TREATMENT OF CONDITIONS THROUGH ELECTRICAL MODULATION OF THE AUTONOMIC NERVOUS SYSTEM

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INTRODUCTION

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. § 119(e) to U.S. provisional application no. 60/477070 filed June 9, 2003, to U.S. provisional application no. 60/482593 filed June 24, 2003 and to U.S. provisional application no. 60/494260 filed August 11, 2003, the disclosures of which are incorporated herein by reference in their entirety.

Field of the Invention

[0001] The field of this invention is the treatment of conditions associated with the autonomic nervous system and more specifically the treatment of conditions through electrical modulation of the autonomic nervous system.

Background of the Invention

[0002] There are a variety of conditions that can affect an individual's health and well-being. The treatment of various conditions that affect the health and well-being of an individual has been around for centuries. Such treatments include pharmacological, surgical, and life style (dietetic, exercise, etc.) changes. In general, the armament of treatment options available to a physician to treat such conditions has increased tremendously, especially in the last century.

[0003] However, while the number of treatment options has increased, typically such options are merely palliative, i.e., are designed for the relief of symptoms of a condition rather than actually being curative of the disorder itself. In fact, treatment protocols effectively directed at the underlying cause of a condition are quite rare.

[0004] As such, there continues to be an interest in the development of new protocol

options for treating conditions. Of particular interest are protocols for treating conditions that are directed at the cause of the condition rather than the symptoms thereof.

SUMMARY OF THE INVENTION

[0005] Methods are provided for treating a subject for a condition caused by an abnormality in the subject's autonomic nervous system. In accordance with the subject methods, at least a portion of a subject's autonomic nervous system is electrically modulated to increase the parasympathetic activity/sympathetic activity ratio in a manner that is effective to treat the subject for the condition. Certain embodiments include electrically modulating at least a portion of a subject's autonomic nervous system by inhibiting and/or increasing activity in at least a portion of the subject's autonomic nervous system. The subject methods find use in the treatment of a variety of different conditions, where such conditions include various disease conditions. Also provided are systems and kits for use in practicing the subject methods.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0006] FIG. 1 shows an exemplary embodiment of an electrostimulatory device operatively positioned in a subject's body in accordance with the subject methods.

DETAILED DESCRIPTION OF THE INVENTION

[0007] Methods are provided for treating a subject for a condition caused by an abnormality in the subject's autonomic nervous system. In accordance with the subject methods, at least a portion of a subject's autonomic nervous system is electrically modulated to increase the parasympathetic activity/sympathetic activity ratio in a manner that is effective to treat the subject for the condition. Certain embodiments include electrically modulating at least a portion of a subject's autonomic nervous system by inhibiting and/or increasing activity in at least a portion of the subject's autonomic nervous system. The subject methods find use in the treatment of a variety of different conditions, where such conditions include various disease conditions. Also provided are systems and kits for use in practicing the subject methods.

[0008] Before the present invention is described, it is to be understood that this invention is not limited to particular embodiments described, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

[0009] Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range is encompassed within the invention. The upper and lower limits of these smaller ranges may independently be included in the smaller ranges is also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the invention.

[0010] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the present invention, the preferred methods and materials are now described. All publications mentioned herein are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited.

[0011] It must be noted that as used herein and in the appended claims, the singular forms "a", "an", and "the" include plural referents unless the context clearly dictates otherwise.

[0012] The publications discussed herein are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided may be different from the actual publication dates which may need to be independently confirmed.

[0013] As will be apparent to those of skill in the art upon reading this disclosure, each of the individual embodiments described and illustrated herein has discrete components and features which may be readily separated from or combined with the features of any of the

other several embodiments without departing from the scope or spirit of the present invention.

[0014] The figures shown herein are not necessarily drawn to scale, with some components and features being exaggerated for clarity.

[0015] As summarized above, the subject invention provides methods for treating a subject for a condition caused by an abnormality in the subject's autonomic nervous system by electrically modulating at least a portion of the subject's autonomic nervous system to increase the parasympathetic activity/sympathetic activity ratio. In further describing the subject invention, representative embodiments of the subject methods are described first in greater detail, followed by a review of various representative applications in which the subject methods may find use. Next, a review of systems and kits for use in the subject methods is provided.

METHODS

[0016] As noted above, the subject methods are methods for treating a subject for a condition caused by an abnormality in the subject's autonomic nervous system. More specifically, the subject methods are methods for treating a subject for a condition caused by an abnormality in a subject's autonomic nervous system by electrically modulating at least a portion of the subject's autonomic nervous system to increase the parasympathetic activity/sympathetic activity ratio in a manner effective to treat the subject for the condition. Accordingly, the subject invention includes electrically modulating at least a portion of a subject's autonomic nervous system to increase the parasympathetic activity/sympathetic activity ratio, i.e., increase parasympathetic activity relative to sympathetic activity. In accordance with the subject invention, increasing the parasympathetic activity/sympathetic activity ratio may be achieved by stimulating the parasympathetic system to increase activity in at least a portion of the parasympathetic system, e.g., stimulating at least one parasympathetic nerve fiber. Alternatively or in addition to stimulating at least one parasympathetic nerve fiber to increase activity, increasing the parasympathetic activity/sympathetic activity ratio may be achieved by inhibiting activity in the sympathetic system, e.g., inhibiting activity in at least one sympathetic nerve fiber. Accordingly, the subject methods include providing electrical

stimulation to at least a portion of a subject's autonomic nervous system, where such electrical stimulation may be excitatory or inhibitory and in certain embodiments may include both excitatory and inhibitory stimulation. Specifically, the subject invention includes electrically stimulating at least a portion of a subject's autonomic nervous system to achieve a desired parasympathetic activity/sympathetic activity ratio, i.e., a desired balance between parasympathetic activity and sympathetic activity, analogous to a parasympathetic activity/sympathetic activity ratio observed in a healthy (i.e., a subject not experiencing an abnormality in the autonomic nervous system), "like" or rather analogous subject, e.g., a healthy human subject ranging in age from about 20 years old to about 25 years old (subjects other than humans will have analogous age ranges). For example, if the subject being treated is a human subject, the parasympathetic activity/sympathetic activity ratio provided by the subject invention is analogous to the parasympathetic activity/sympathetic activity ratio observed in a healthy human ranging in age from about 20 years old to about 25 years old.

[0017] Before further describing the subject methods, a review of the autonomic nervous system is provided to provide a proper foundation for the subject invention.

Review of the Autonomic Nervous System

[0018] The nervous system is divided into the somatic nervous system and the autonomic nervous system ("ANS"). In general, the somatic nervous system controls organs under voluntary control (e.g., skeletal muscles) and the ANS controls individual organ function and homeostasis. For the most part, the ANS is not subject to voluntary control. The ANS is also commonly referred to as the visceral or automatic system.

[0019] The ANS can be viewed as a "real-time" regulator of physiological functions which extracts features from the environment and, based on that information, allocates an organisms' internal resources to perform physiological functions for the benefit of the organism, e.g., responds to environment conditions in a manner that is advantageous to the organism.

[0020] The ANS conveys sensory impulses to and from the central nervous system to various structures of the body such as organs and blood vessels, in addition to conveying sensory impulses through reflex arcs. For example, the ANS controls constriction and

dilatation of blood vessels; heart rate; the force of contraction of the heart; contraction and relaxation of smooth muscle in various organs; lungs; stomach; colon; bladder; visual accommodation, secretions from exocrine and endocrine glands, etc. The ANS does this through a series of nerve fibers and more specifically through efferent and afferent nerves. The ANS acts through a balance of its two components: the sympathetic nervous system and parasympathetic nervous system, which are two anatomically and functionally distinct systems. Both of these systems include myelinated preganglionic fibers which make synaptic connections with unmyelinated postganglionic fibers, and it is these fibers which then innervate the effector structure. These synapses usually occur in clusters called ganglia. Most organs are innervated by fibers from both divisions of the ANS, and the influence is usually opposing (e.g., the vagus nerve slows the heart, while the sympathetic nerves increase its rate and contractility), although it may be parallel (e.g., as in the case of the salivary glands). Each of these is briefly reviewed below.

The Parasympathetic System

[0021] The parasympathetic nervous system is the part of the autonomic nervous system controlling a variety of autonomic functions including, but not limited to, involuntary muscular movement of blood vessels and gut and glandular secretions from eye, salivary glands, bladder, rectum and genital organs. The vagus nerve is part of the parasympathetic system. Parasympathetic nerve fibers are contained within the last five cranial nerves and the last three spinal nerves and terminate at parasympathetic ganglia near or in the organ they supply. The actions of the parasympathetic system are broadly antagonistic to those of the sympathetic system, lowering blood pressure, slowing heartbeat, stimulating the process of digestion etc. The chief neurotransmitter in the parasympathetic system is acetylcholine.

[0022] More specifically, neurons of the parasympathetic nervous system emerge from the brainstem as part of the Cranial nerves III, VII, IX and X (vagus nerve) and also from the sacral region of the spinal cord via Sacral nerves 2, 3 and 4. Because of these origins the parasympathetic nervous system is often referred to as the 'craniosacral outflow'.

[0023] In the parasympathetic nervous system both pre- and postganglionic neurons are cholinergic (i.e., they utilize the neurotransmitter acetylcholine) Unlike adrenaline and

noradrenaline, which the body takes around 90 minutes to metabolize, acetylcholine is rapidly broken down after release by the enzyme cholinesterase. As a result the effects are relatively brief in comparison to the sympathetic nervous system.

[0024] Each preganglionic parasympathetic neuron synapses with just a few postganglionic neurons, which are located near - or in - the effector organ, a muscle or gland. As noted above, the primary neurotransmitter in the parasympathetic system is acetylcholine ("Ach") such that ACh is the neurotransmitter at all the pre- and many of the postganglionic neurons of the parasympathetic system. However, some of the postganglionic neurons release nitric oxide as their neurotransmitter.

The Sympathetic System

[0025] The sympathetic nervous system is the part of the autonomic nervous system comprising nerve fibers that leave the spinal cord in the thoracic and lumbar regions and supply viscera and blood vessels by way of a chain of sympathetic ganglia running on each side of the spinal column which communicate with the central nervous system via a branch to a corresponding spinal nerve. The sympathetic nervous system controls a variety of autonomic functions including, but not limited to, control of movement and secretions from viscera and monitoring their physiological state, stimulation of the sympathetic system inducing e.g. the contraction of gut sphincters, heart muscle and the muscle of artery walls, and the relaxation of gut smooth muscle and the circular muscles of the iris. The chief neurotransmitter in the sympathetic system is adrenaline which is liberated in the heart, visceral muscle, glands and internal vessels, with acetylcholine acting as a neurotransmitter at ganglionic synapses and at sympathetic terminals in skin and skeletal muscle blood vessels. The actions of the sympathetic system tend to be antagonistic to those of the parasympathetic system.

[0026] More specifically, the preganglionic motor neurons of the sympathetic system arise in the spinal cord. They pass into sympathetic ganglia which are organized into two chains that run parallel to and on either side of the spinal cord. The neurotransmitter of the preganglionic sympathetic neurons is acetylcholine ("Ach") which stimulates action potentials in the postganglionic neurons.

[0027] The neurotransmitter released by the postganglionic neurons is nonadrenaline (also called norepinephrine). The action of noradrenaline on a particular structure such as a gland or muscle is excitatory is some cases, inhibitory in others. At excitatory terminals, ATP may be released along with noradrenaline.

[0028] Activation of the sympathetic system may be characterized as general because a single preganglionic neuron usually synapses with many postganglionic neurons and the release of adrenaline from the adrenal medulla into the blood ensures that all the cells of the body will be exposed to sympathetic stimulation even if no postganglionic neurons reach them directly.

[0029] As indicated above, the subject invention provides methods of treating a subject for a condition caused by an abnormality in the subject's autonomic nervous system by electrically modulating at least a portion of the subject's autonomic nervous system to increase the parasympathetic activity/sympathetic activity ratio or increase parasympathetic activity relative to sympathetic activity. By "electrically modulating at least a portion of a subject's autonomic nervous system" is meant altering or changing at least a portion of an autonomic nervous system by electrical means to provide a change, alteration or shift in at least one component or aspect of the autonomic nervous system, as will be described in greater detail below. The modulation of the autonomic nervous system may affect central motor output and/or nerve conduction and/or transmitter release and/or synaptic transmission and/or receptor activation, but in any event is a change that provides an increase in the parasympathetic activity/sympathetic activity ratio (as used herein, "activity" and "function' are used interchangeably). For example, at least a portion of the autonomic nervous system may be electrically modulated to alter, shift or change parasympathetic activity and/or sympathetic activity from a first state to a second state, where the second state is characterized by an increase in the parasympathetic activity/sympathetic activity ratio relative to the first state. In certain embodiments, the subject invention provides methods of increasing activity in at least one parasympathetic nerve fiber to achieve an increase in the parasympathetic activity/sympathetic activity ratio. In certain embodiments the subject invention provides methods of inhibiting

activity in at least one sympathetic nerve fiber to achieve an increased parasympathetic activity relative to sympathetic activity. Still further, in certain embodiments the subject invention provides methods of both increasing activity in at least one parasympathetic nerve fiber and inhibiting activity in at least one sympathetic nerve fiber to achieve the desired result. Certain embodiments include electrically stimulating, e.g., with long-term low frequency stimulation, to inhibit or depress activity in the sympathetic nervous system.

[0030] Accordingly, a feature of the subject methods is that the ratio of parasympathetic activity to sympathetic activity is increased. By increased ratio of parasympathetic activity to sympathetic activity is meant that this ratio is increased in at least a portion of the autonomic nervous system, where the increase is at least great enough to treat a given condition. While the ratio of parasympathetic function/sympathetic function is increased, the net result may be a parasympathetic bias (i.e., parasympathetic dominance), sympathetic bias (i.e., sympathetic dominance) or the activities of the parasympathetic system and sympathetic system may be equal (i.e., neither is dominant).

[0031] In practicing the subject methods, at least a portion of a subject's autonomic nervous system is electrically modulated to increase parasympathetic activity relative to sympathetic activity (i.e., increase parasympathetic activity/sympathetic activity ratio). As noted above, the electrical modulation may provide an increase in function of at least a portion of the autonomic system, e.g., increase function in at least one parasympathetic nerve fiber, and/or provide a decrease in function or dampening of a portion of the autonomic system, e.g., may inhibit activity in at least one sympathetic nerve fiber or inhibit nerve pulse transmission. As the subject methods electrically modulate at least a portion of a subject's autonomic nervous system, the electrical modulation may be systemic or regional (i.e., local). In other words, the entire parasympathetic and/or sympathetic systems may be modulated or only a portion of the parasympathetic and/or sympathetic systems may be modulated, but in any event at least one parasympathetic and/or sympathetic nerve fiber is affected in a particular manner to the desired increase in parasympathetic activity relative to sympathetic activity. As will be described in greater detail below, any part of the subject methods may be performed manually or automatically.

Increasing Activity in At Least a Portion of the Parasympathetic Nervous System

[0032] As noted above, in certain embodiments activity in at least a portion of the parasympathetic system may be increased to modulate at least a portion of the autonomic nervous system. For example, any portion of the parasympathetic system, e.g., one or more nerve fibers, may be electrically stimulated to increase parasympathetic activity to provide the desired ratio of parasympathetic/sympathetic activity. In other words, activity in at least a portion of the parasympathetic nervous system may be increased by electrical stimulation such that at least a portion of the parasympathetic nervous system may be "up-regulated".

[0033] Increasing activity in, or up-regulating, at least a part of the parasympathetic system may be desired in instances where, prior to the electrical stimulation of, e.g., the at least one parasympathetic nerve fiber, sympathetic activity is higher than parasympathetic activity (i.e., there exists a relative sympathetic bias) and as such the subject methods may be employed to increase parasympathetic activity to a level above or rather to a level that is greater than sympathetic activity or may be employed to modulate the differential between the parasympathetic-sympathetic systems such that the result of increasing parasympathetic activity may be a sympathetic bias, parasympathetic bias or may be an equalization of the two systems (i.e., the activities of the two systems are approximately equal- including equal), but the difference between the parasympathetic-sympathetic systems may be modulated, e.g., reduced or minimized or increased in certain embodiments. Accordingly, the subject methods may be employed to increase parasympathetic activity above that of sympathetic activity and/or may be employed to modulate (increase or decrease) the differential between the two systems, but in any event is employed to increase the ratio of parasympathetic activity to sympathetic activity. In those instances where there exists a sympathetic bias prior to increasing parasympathetic activity, the cause of the sympathetic bias may be manifold, e.g., hyperthermia, infection, inflammation and fever are potential causes of sympathetic bias (see for example Rowell LB. Hyperthermia: a hyperadrenergic state. Hypertension 1990; 15(5):505-507). In certain embodiments, a sympathetic bias may be the normal state, but the ratio of the two systems may be abnormal. Furthermore, increasing

parasympathetic bias may also be desired in instances where, prior to the electrical stimulation of, e.g., the at least one parasympathetic nerve fiber, to increase parasympathetic activity, parasympathetic activity is higher than the sympathetic activity, but the differential between the two needs to be modulated such as increased further, e.g., the sympathetic activity is normal or above normal (i.e., abnormally high) and/or the parasympathetic activity is normal or below normal (i.e., abnormally low) or above normal (i.e., abnormally low). For example, such instances may occur where a subject has normal or above normal parasympathetic function, but also has elevated sympathetic function. Other instances include below normal parasympathetic function, but normal or elevated sympathetic function, etc. It may also be desirable to increase parasympathetic function in instances where the respective activities of the two system are analogous or approximately equal, including equal, prior to increasing activity in the parasympathetic system, but the level of one or both is abnormally high or abnormally low. The above-described examples of instances where increasing parasympathetic activity may be desired is exemplary only and is in no way intended to limit the scope of the invention and other instances where increasing parasympathetic activity to provide an increase in the parasympathetic activity/sympathetic activity ratio may be desired will be apparent to those of skill in the art.

[0034] Specifically, activity in at least a portion of the parasympathetic system, e.g., one or more nerve fibers associated with the parasympathetic system, is increased by an electrostimulatory device positioned directly on or about (i.e., adjacent) the targeted area of the parasympathetic system, as will be described in greater detail below. Accordingly, in practicing the subject methods to increase the parasympathetic activity/sympathetic activity ratio by increasing activity in at least one area of the parasympathetic system such as a nerve fiber, an electrostimulatory device is operatively positioned directly on or about the one or more parasympathetic nerve fibers to which an increase in activity is desired.

[0035] The actual area(s) of the parasympathetic nervous system that will be electrically stimulated will vary in accordance with the subject invention, and include pre- and post ganglionic nerve fibers, as well as ganglionic structures, efferent and afferent nerve fibers, synapses, etc., and combinations thereof in certain embodiments. In certain

embodiments, a given nerve fiber may be electrically stimulated in more than one area of the nerve fiber. Targeted areas of the parasympathetic nervous system which may be electrically stimulated in accordance with the subject invention include, the oculomotor nerve; facial nerve; glossopharyngeal nerve; hypoglossal nerve; trigeminal nerve, vagus nerve including the recurrent laryngeal branches of the vagus nerve, the pharyngeal and superior laryngeal branches of the vagus nerve, the cardiac branches of the vagus nerve, the anterior vagal trunk and the posterior vagal trunk; ciliary ganglion; pterygophalatine ganglion; vidian nerve, pterygopalatine nerve, otic ganglion; chorda tympsubmandibular ganglion; lingual nerve; submandibular ganglion; esophageal plexus; parasympathetic branch from inferior hypogastric plexus to descending colon; rectal plexus and pelvic planchnic nerves, or a combination of two or more of the above. For example, in certain embodiments electrical stimulation to the vagus may be employed and/or to the hypoglossal nerve and/or to the trigeminal nerve.

[0036] Once an electrostimulatory device is positioned in a suitable position on or about one or more targeted parasympathetic areas such as one or more parsympathetic nerve fibers, the area(s) (e.g., the targeted nerve fiber(s)) are electrically stimulated for a period of time sufficient to provide the desired increase in parasympathetic activity. This period of time will vary depending on the area (e.g., the nerve fiber) being treated, the condition being treated, etc. Certain embodiments include simultaneously monitoring (i.e., in "real time") the parasympathetic activity (and/or sympathetic activity) such that a given nerve fiber is electrically stimulated until the desired increase in parasympathetic activity (parasympathetic activity/sympathetic activity balance) is observed. Still further, inmany embodiments once the desired increase in parasympathetic activity is achieved, a given area of the parasympathetic system (e.g., a given parasympathetic nerve fiber) may be repeatedly electrically stimulated one or more times to maintain the desired state such that the subject methods may be repeated one or more times, i.e., the subject methods include chronically stimulating at least one area of the parasympathetic nervous system such as chronically stimulating one or more parasympathetic nerve fibers. For example, in certain embodiments electrical stimulation (e.g., intermittent mild electrical pulses) may be delivered to a given area of the parasympathetic nervous system, e.g., one or

more nerve fibers of the parasympathetic system, twenty-four hours a day for a period of days, weeks, months, or even years in certain embodiments.

[0037] During the period of time that a given area of the parasympathetic nervous system such as a parasympathetic nervous system nerve fiber is electrically stimulated, the electrical stimulation may be substantially continuous, including continuous or intermittent (i.e., pulsed or periodic), where in many embodiments the electrical stimulation is in the form of electrical pulses. In other words, in certain embodiments a given area of the parasympathetic nervous system (e.g., a given nerve fiber) may be continuously electrically stimulated during the above-described period of time and in certain other embodiments a given area of the parasympathetic nervous system (e.g., a given nerve fiber) may be pulsed or intermittently electrically stimulated during the period of time described above.

[0038] In accordance with the subject methods to electrically stimulate at least one area of the parasympathetic nervous system such as at least one parasympathetic nerve fiber, once operatively positioned the electrostimulatory device is activated to provide an electrical signal to the targeted area such as to one or more parasympathetic nerve fiber(s) in a manner to increase the parasympathetic activity at least in the area being electrically stimulated and in certain instances in adjacent areas or in the entire parasympathetic system, e.g., systemically in certain instances. For example, many nerve fibers of the parasympathetic system are in close proximity and thus electrical stimulation to one nerve fiber may also increase activity in one or more other nerve fibers, e.g., nerve fibers in close proximity thereto.

[0039] In practicing the subject methods, activation of the electrostimulatory device directly applies the electrical output of the device, i.e., electrical impulses, to the targeted area. The exact parameters of the electrical stimulation may vary depending on the particular subject, condition being treated, etc. Usually, an electronic current wave is provided when the electrical stimulation is applied. In certain embodiments, the current wave includes current waves of high frequency, e.g., high frequency pulses, where the current wave may also include low frequency amplitude modulation. In certain embodiments, a plurality of high frequency bursts of current pulses may be applied in

addition to the application of underlying low frequency continuous stimulus. Stimulation may be monopolar or multipolar.

[0040] For example, to stimulate a portion of the parasympathetic nervous system, voltage or intensity may range from about 1 millivolt to about 1 volt or more, e.g., 0.1 volt to about 50 volts, e.g., from about 0.2 volt to about 20 volts and the frequency may range from about 1 Hz to about 2500 Hz, e.g., about 1 Hz to about 1000 Hz, e.g., from about 2 Hz to about 100 Hz in certain embodiments. In certain embodiments a pure d-c voltages may be employed. The pulse width may range from about 1 microsecond to about 2000 microseconds or more, e.g., from about 10 microseconds to about 2000 microseconds, e.g., from about 15 microseconds to about 1000 microseconds, e.g., from about 25 microseconds to about 1000 microseconds. The electrical output may be applied for at least about 1 millisecond or more, e.g., about 1 second, e.g., about several seconds, where in certain embodiments the stimulation may be applied for as long as about 1 minute or more, e.g., about several minutes or more, e.g., about 30 minutes or more may be used in certain embodiments.

[0041] Certain embodiments may include providing long-term potentiation ("LTP") of at least a portion of the parasympathetic nervous system. LTP may be characterized as an enduring increase in synaptic efficacy resulting from high-frequency stimulation of an afferent (input) pathway. For example, long-term high frequency stimulation of at least a portion of the parasympathetic system may be employed to achieve parasympathetic bias. More specifically, rapid, intense electrical stimulation of presynaptic neurons associated with the parasympathetic system may be employed to evoke action potentials in one or more postsynaptic neurons such that over time these synapses become increasingly sensitive. This constant level of presynaptic stimulation eventually becomes converted into a larger postsynaptic output which may last for minutes, hours, days, even weeks or more.

[0042] In certain embodiments the subject methods may also include detecting information related to one or more aspects of the autonomic nervous system such as a physical and/or chemical aspect, e.g., activity, balance, etc., in at least a portion of the autonomic nervous system and evaluating this information to determine the state of the autonomic nervous system, e.g., the parasympathetic activity and/or sympathetic activity.

Once the state of the autonomic nervous system is determined, it may be evaluated in regards to whether the autonomic nervous system is in an abnormal state or in need of modulation, e.g., whether activity in at least a portion of the parasympathetic system needs to be increased to increase the parasympathetic activity / sympathetic activity ratio such that this analysis may be employed as a "trigger" to providing electrical modulation of at least a portion of the autonomic nervous system wherein modulation is not performed unless the analysis determined such is necessary. Accordingly, collecting and evaluating this type of data and relating it to whether modulation is required may be employed as a "trigger" to electrically modulating at least a portion of the autonomic nervous system (e.g., performed prior to, during or following a stimulation protocol) such that such data may indicate whether, when, etc., electrical modulation is required – if at all. For example, in certain embodiments electrical modulation of at least a portion of a subject's autonomic nervous system is not performed unless one or more aspects of the autonomic nervous system are detected and indicate such modulation is necessary. Any suitable physical and/or chemical aspect or indicator of the autonomic nervous system may be employed, e.g., conduction, catecholamine levels, heart rate variability ("HRV"), action potentials, QT interval, etc. In certain embodiments, detection may include detecting the activity or function of a particular organ or system under the control of the autonomic nervous system such as detecting rennin levels for the digestive system, etc. Any suitable detection means may be employed to detect relevant information about the autonomic nervous system, as will be described below.

[0043] In certain embodiments, a control feedback loop is provided. For example, during or following a particular stimulation protocol, the parasympathetic activity (and/or sympathetic activity) may be monitored, e.g., by sensing conduction in at least a portion of the parasympathetic system, e.g., in a particular electrically stimulated nerve fiber, or by any suitable method. Other methods that may be employed to monitor the autonomic balance include, but are not limited to, neurography, continuous or serial measurements of circulating catecholamine levels, heart rate variability ("HRV"), post-ganglionic action potentials, QT interval, and the like (see for example Rang S, Wolf H, Montfrans GA, Karemaker JM. Non-invasive assessment of autonomic cardiovascular control in normal pregnancy and pregnancy-associated hypertensive disorders: a review. J Hypertens

2002;20(11):2111-9). For example, a sensor suitable for detecting nerve cell or axon activity that are related to the autonomic nervous system may be implanted in a portion of a subject's body. A sensor may take the form of an electrode or the like. Signals received by such a sensor may be amplified before further processing. A sensor may also take the form of a device capable of detecting nerve compound action potentials or may take the form of a transducer that includes an electrode with an ion selective coating applied which is capable of directly transducing the amount of a particular transmitter substance or its breakdown by-products. In utilizing a feedback system, if the desired increase in parasympathetic activity is not detected, e.g., prior to, during or after a particular stimulus is applied to the parasympathetic system, the same or a different stimulus protocol may be performed. For example, in those instances where a different protocol is performed, one or more of the stimulus parameters may be modified, e.g., the pulse width may be increased, or the like, in the second protocol.

Inhibiting Activity in At Least a Portion of the Sympathetic Nervous System

[0044] As noted above, in certain embodiments activity in at least a portion of the sympathetic system may be inhibited to modulate at least a portion of the autonomic nervous system. For example, activity in any portion of the sympathetic nervous system may be inhibited to increase parasympathetic activity relative to sympathetic activity to provide the desired ratio of parasympathetic/sympathetic activity, e.g., activity in one or more sympathetic nerve fibers may be inhibited. By "inhibited" is meant to include disruption, down-regulating, dampening and partial and complete blockage of nerve impulses in a particular area of the sympathetic system.

[0045] Inhibiting or "down-regulating" activity in at least a part of the parasympathetic system may be desired in instances where, prior to the inhibition of activity in, e.g., at least one sympathetic nerve fiber, the sympathetic activity is higher than desired. For example, sympathetic activity may be higher than the parasympathetic activity (i.e., there exists a sympathetic bias) or sympathetic activity may be less than or approximately equal to, including equal, to parasympathetic activity, and the subject methods may be employed to modulate the differential between the parasympathetic-sympathetic systems such that the result of decreasing sympathetic activity may be a sympathetic bias,

parasympathetic bias or may be an equalization of the two systems (i.e., the activities of the two systems are approximately equal- including equal), but the difference between the parasympathetic-sympathetic systems may be modulated, e.g., increased or reduced in certain embodiments. Accordingly, the subject methods may be employed to decrease sympathetic activity below that of sympathetic activity and/or may be employed to modulate (decrease or increase) the differential between the two systems, but in any event is employed to increase the ratio of parasympathetic activity to sympathetic activity. For example, decreasing activity in at least a portion of the sympathetic system may be employed where there is a normal or an abnormally low parasympathetic function and/or abnormally high sympathetic function. Such may also be desired in instances where, prior to decreasing sympathetic function in, e.g., at least one sympathetic nerve fiber, parasympathetic activity is higher than the sympathetic activity, but the differential between the two needs to be increased further. For example, such instances may occur where a subject has normal or above normal (i.e., abnormally high) parasympathetic function, but also has elevated sympathetic function (i.e., abnormally high), e.g., a relative bias towards sympathetic function may be present. Other instances include normal or below normal (i.e., abnormally low) parasympathetic activity and/or normal or above normal (i.e., abnormally high) sympathetic activity. The above-described examples of instances where decreasing sympathetic activity may be desired is exemplary only and is in no way intended to limit the scope of the invention and other instances where decreasing sympathetic activity to provide an increase in the parasympathetic activity/sympathetic activity ratio may be desired will be apparent to those of skill in the art.

[0046] Inhibiting or down-regulating at least a portion of the sympathetic nervous system may be accomplished in a number of ways. For example, inhibition or down-regulation of activity may be achieved by surgically isolating an effector structure (i.e., the target of the sympathetic activity) from sympathetic innervation, i.e., surgically isolating an effector structure from one or more sympathetic nerve fibers associated with it. Furthermore, sympathetic nerves may be ablated, permanently or reversibly, by employing energy delivery devices or cryotherapy. Certain embodiments may employ cryoablation, thermoablation, microwave energy, focus ultrasound, magnetic fields

including internal and external magnetic fields, laser energy, optical energy, radiofrequency energy, and the like. The sympathetic system may also be inhibited or down-regulated or depressed by employing pacing mechanisms such as implantable electrode-based pacing systems, external magnetic-based pacing system, and the like. Certain embodiments may include inhibiting activity in at least a portion of the sympathetic nervous system using transcutaneous electrical nerve stimulation ("TENS") or transmagentic stimulation ("TMS") (see for example George, M. Stimulating the Brain. Sci Amer 2003 Sept.). Still further, pharmacological agents such as neurotoxins may be employed to disable sympathetic function such that the parasympathetic to sympathetic ratio is increased temporarily or permanently. In any event, activity in at least a portion of the sympathetic system, e.g., one or more nerve fibers associated with the sympathetic system, is inhibited. In many embodiments, this inhibition is achieved by employing an electrostimulatory device positioned directly on or about (i.e., adjacent) the targeted area of the sympathetic system, as will be described in greater detail below. Accordingly, in practicing the subject methods to increase parasympathetic activity relative to sympathetic activity by inhibiting activity in at least one area of the sympathetic system such as a nerve fiber, an electrostimulatory device may be operatively positioned directly on or about the one or more sympathetic nerve fibers desired to be inhibited.

[0047] The actual area(s) of the sympathetic nervous system that will be inhibited will vary, and include pre- and post ganglionic nerve fibers, ganglionic structures, efferent and afferent nerve fibers, etc. In certain embodiments, a given nerve fiber may be electrically inhibited in more than one area of the nerve fiber. Targeted areas of the sympathetic nervous system which may be inhibited or dampened in accordance with the subject invention include, internal carotid nerve and plexus, middle and superior cervical sympathetic ganglion; vertebral ganglion; cervicothoracic ganglion; sympathetic trunk; cervical cardiac nerves; cardiac plexus; thoracic aortic plexus; celiac ganglion; celiac trunk and plexus; superior mesenteric ganglion; superior mesenteric artery and plexus; intermesenteric plexus; inferior mesenteric ganglion; inferior mesenteric artery and plexus; superior hypogastric plexus; hypogastric nerves; vesical plexus; thoracic cardiac nerves; sympathetic trunk; 6th thoracic sympathetic ganglion; gray and white rami

communicantes; greater, lesser and least splanchnic nerves; aorticorenal ganglion; lumbar splanchnic nerves; gray rami communicantes and sacral splanchnic nerves; or a combination of two or more of the above.

[0048] In practicing the subject methods to inhibit sympathetic activity, once an electrostimulatory device is positioned in a suitable position on or about one or more targeted sympathetic areas such as one or more sympathetic nerve fibers, an electrical output, impulse or signal is applied for a period of time sufficient to provide the desired inhibition and thus the desired ratio of parasympathetic activity to sympathetic activity. This period of time will vary depending on the area (e.g., the nerve fiber) being inhibited and the desired degree of inhibition, the condition being treated, etc.

[0049] Analogous to that described above in regards to monitoring activity in at least a portion of the parasympathetic system, certain embodiments include simultaneously monitoring (i.e., in "real time") the inhibition in the targeted area or sympathetic activity (and/or parasympathetic activity) such that an electrical output or impulse is applied to a given nerve fiber until the desired inhibition in activity (parasympathetic activity/sympathetic activity balance) is observed. Still further, in many embodiments once the desired increase in parasympathetic activity is achieved by inhibiting activity in a portion of the sympathetic nervous system, a given area of the sympathetic system (e.g., a given sympathetic nerve fiber) may be repeatedly subjected to electrical impulses one or more times to maintain the desired state such that the subject methods may be repeated one or more times, i.e., the subject methods include chronically applying electrical impulses to at least one area of the sympathetic nervous system. For example, in certain embodiments electrical impulses (e.g., intermittent mild electrical pulses) may be delivered to a given area of the sympathetic nervous system, e.g., one or more nerve fibers of the sympathetic system) twenty-four hours a day for a period of days, weeks, months, or even years in certain embodiments.

[0050] During the period of time that the activity in a given area of the sympathetic nervous system, such as a sympathetic nervous system nerve fiber, is inhibited, the electrical impulses may be applied substantially continuously, including continuously or intermittently (i.e., pulsed or periodic). In other words, in certain embodiments a given area of the sympathetic nervous system may be subjected to continuously applied

electrical impulses during the above-described period of time and in certain other embodiments a given area of the sympathetic nervous system may be pulsed or intermittently electrically inhibited during the period of time described above.

[0051] In accordance with the subject methods to inhibit activity in at least one area of the sympathetic nervous system such as at least one sympathetic nerve fiber, once operatively positioned the electrostimulatory device is activated to provide an electrical impulse to the targeted area such as one or more sympathetic nerve fiber(s) in a manner to modulate the sympathetic activity in at least in the area being subjected to the electrical impulses and in certain instances in adjacent areas, e.g., systemically in certain instances. Activation of the electrostimulatory device directly applies the electrical output, i.e., electrical impulses, of the device to the targeted area to inhibit activity. The exact parameters of the electrical impulse may vary depending on the particular subject, condition being treated, etc. In certain embodiments, a negative current wave is provided and employed to inhibit sympathetic activity. In certain embodiments, the current wave includes current waves of high frequency, e.g., high frequency pulses, where the current wave may also include low frequency amplitude modulation. In certain embodiments, a plurality of high frequency bursts of current pulses may be applied in addition to the application of underlying low frequency continuous stimulus. Monopolar or bipolar technologies may be employed.

[0052] For example, to inhibit conduction in a portion of the sympathetic nervous system, voltage or intensity may range from about 1 millivolt to about 1 volt or more, e.g., 0.1 volt to about 50 volts, e.g., from about 0.2 volt to about 20 volts and the frequency may range from about 1 Hz to about 2500 Hz, e.g., about 50 Hz to about 2500 Hz. In certain embodiments a pure d-c voltages may be employed. The pulse width may range from about 1 microseconds to about 2000 microseconds or more, e.g., from about 10 microseconds to about 2000 microseconds, e.g., from about 15 microseconds to about 1000 microseconds, e.g., from about 25 microseconds to about 1000 microseconds. The stimulation may be applied for at least about 1 millisecond or more, e.g., about 1 second, e.g., about several seconds, where in certain embodiments the electrical energy may be applied for as long as about 1 minute or more, e.g., about several minutes or more, e.g., about 30 minutes or more may be used in certain embodiments.

[0053] In certain embodiments, electrical stimulation of at least a portion of the sympathetic system may be employed to depress signal in the sympathetic system over a long period of time. For example, long-term depression ("LTD") may be achieved by applying long-term low frequency stimulation to at least a portion of the sympathetic system to provide long-term sympathetic suppression. Specifically, slow, weak stimulation may be applied to at least a portion of the sympathetic system, e.g., neurons of the sympathetic system, to bring about long-term changes in the synapses, such as a reduction in sensitivity.

[0054] As described above in regards to detecting aspects of the parasympathetic system, certain embodiments of the subject methods may also include detecting information related to one or more physical and/or chemical aspects or states of the autonomic nervous system, e.g., activity, balance, etc., in at least a portion of the autonomic nervous system and evaluating this information to determine the state of the autonomic nervous system, e.g., the parasympathetic activity and/or sympathetic activity. Once the state of the autonomic nervous system is determined, it may be evaluated in regards to whether the autonomic nervous system is in an abnormal state or in need of modulation, e.g., whether activity in at least a portion of the sympathetic needs to be inhibited to increase parasympathetic activity relative to sympathetic activity. Accordingly, analogous methods as those described above may be applied to detecting one or more aspects of the sympathetic system and determining whether inhibition in activity in at least a portion of the sympathetic system is required, e.g., prior to, during or after a given inhibition protocol has been performed.

[0055] Analogous to that described for the electrical stimulation of a portion of the parasympathetic nervous system, in certain embodiments of inhibiting sympathetic activity a control feedback loop is provided. For example, during or following a particular inhibition protocol, the amount of activity that is inhibited and/or the resultant sympathetic activity and/or parasympathetic activity may be monitored, e.g., by sensing activity in at least a portion of the sympathetic system. Other methods that may be employed to monitor the autonomic balance include, but are not limited to, neurography, continuous or serial measurements of circulating catecholamine levels, heart rate variability ("HRV"), post-ganglionic action potentials, QT interval, and the like (see for

example Rang S, Wolf H, Montfrans GA, Karemaker JM. Non-invasive assessment of autonomic cardiovascular control in normal pregnancy and pregnancy-associated hypertensive disorders: a review. J Hypertens 2002;20(11):2111-9). A sensor analogous to that described above may be employed. For example, a sensor suitable for detecting nerve cell or axon activity that are related to the autonomic nervous system may be implanted in a portion of a subject's body. A sensor may take the form of an electrode. Signals received by such a sensor may be amplified before further processing. A sensor may also take the form of a device capable of detecting nerve compound action potentials or may take the form of a transducer that includes an electrode with an ion selective coating applied which is capable of directly transducing the amount of a particular transmitter substance or its breakdown by-products. In utilizing a feedback system, if the desired increase in parasympathetic activity is not achieved, the same or a different stimulus protocol may be performed. In utilizing such a feedback system, if the desired inhibition in activity or level of sympathetic activity is not achieved, the same or a different protocol for inhibiting activity may be performed. For example, in those instances where a different protocol is performed, one or more of the protocol parameters may be modified, e.g., the pulse width may be increased, or the like, in the second protocol.

Increasing Activity in At Least a Portion of the Parasympathetic Nervous System and Inhibiting Activity in At Least a Portion of the Sympathetic Nervous System

[0056] As noted above, in certain embodiments activity in at least a portion of the parasympathetic system may be increased and activity in at least a portion of the sympathetic system may be inhibited to increase the parasympathetic activity/sympathetic activity ratio. For example, as described above any portion of the parasympathetic nervous system may be electrically stimulated to increase activity and activity in any portion of the sympathetic nervous system may be inhibited to provide the desired ratio of parasympathetic activity to sympathetic activity, e.g., one or more nerve fibers of the parasympathetic system may be electrically stimulated to increase activity and/or the activity in one or more nerve fibers of the sympathetic system may be inhibited. Such a protocol may be employed, e.g., in instances where parasympathetic

function is normal or abnormally low and/or sympathetic function is normal or abnormally high where normal is determined by the typical autonomic nervous system functions for a healthy subject, e.g., a healthy human subject ranging in age from about 20 years old to about 25 years old. Such embodiments may be employed to alter the dominance and/or may be employed to modulate the differential between the two systems. For example, prior to modulating the autonomic system according to the subject invention, the activity in the sympathetic system may be higher than activity in the parasympathetic system and the subject methods may be employed to increase the parasympathetic activity to a level that is greater than the sympathetic activity and/or may be employed to alter the differential or difference in activity levels of the two systems such as decreasing the difference in activity levels or increasing the difference in activity levels. In other embodiments, prior to modulating the autonomic system according to the subject invention, the activity in the parasympathetic system may be higher than activity in the sympathetic system and the subject methods may be employed to alter the differential or difference in activity levels of the two systems such as increasing the difference in activity levels. The above-described examples of instances where increasing activity in at least a portion of the parasympathetic system and decreasing activity in at least a portion of the sympathetic activity may be desired is exemplary only and is in no way intended to limit the scope of the invention and other instances where increasing activity in at least a portion of the parasympathetic system and decreasing activity in at least a portion of the sympathetic activity may be desired will be apparent to those of skill in the art.

[0057] Increasing activity in at least a portion of the parasympathetic system and decreasing activity in at least a portion of the sympathetic system may be performed simultaneously or sequentially such that at least a portion of the parasympathetic nervous system may be electrically stimulated to increase activity therein prior or subsequent to inhibiting activity in at least a portion of the sympathetic nervous system. Regardless of whether increasing activity in at least a portion of the parasympathetic system and decreasing activity in at least a portion of the sympathetic system are performed simultaneously or sequentially, the parameters for increasing activity in at least a portion

of the parasympathetic system and decreasing activity in at least a portion of the sympathetic system are analogous to that described above.

Pharmacological Modulation of the Autonomous Nervous System

[0058] In certain embodiments, the subject methods also include pharmacologically modulating a subject's autonomic nervous system. Such pharmacological modulation may be performed prior to and/or at the same time as and/or subsequent to electrical modulation as described above. That is, in certain embodiments the subject methods may include administering an effective amount of one or more autonomic nervous system pharmacological agents to a subject to modulate the subject's autonomic nervous system. By effective amount is meant a dosage sufficient to modulate at least a portion of a subject's autonomic nervous system for a given period of time. The one or more pharmacological agents may be administered prior to any electrical stimulation of at least a portion of the autonomic nervous system that may be performed and/or prior to any inhibition of activity in at least a portion of the autonomic nervous system that may be performed. Furthermore, the one or more pharmacological agents may be administered simultaneously with any electrical stimulation of at least a portion of the autonomic nervous system that may be performed and/or simultaneously with any inhibition of activity in at least a portion of the autonomic nervous system that may be performed. Still further, the one or more pharmacological agents may be administered subsequent to any electrical stimulation of at least a portion of the autonomic nervous system that may be performed and/or subsequent to any inhibition of activity in at least a portion of the autonomic nervous system that may be performed.

[0059] Depending on the nature of the pharmacological agent, the active agent(s) may be administered to the subject using any convenient means capable of resulting in the desired modulation of the autonomic nervous system. Thus, the pharmacological agent may be incorporated into a variety of formulations for therapeutic administration. More particularly, the agents of the present invention may be formulated into pharmaceutical compositions by combination with appropriate, pharmaceutically acceptable carriers or diluents, and may be formulated into preparations in solid, semi-solid, liquid or gaseous forms, such as tablets, capsules, powders, granules, ointments, solutions, suppositories,

injections, inhalants and aerosols. As such, administration of the agents can be achieved in various ways, including oral, buccal, rectal, parenteral, intraperiactivityal, intradermal, transdermal, intracheal, etc., administration.

[0060] In pharmaceutical dosage forms, the agents may be administered alone or in appropriate association, as well as in combination, with other pharmaceutically active compounds. The following methods and excipients are merely exemplary and are in no way limiting.

[0061] For oral preparations, the agents may be used alone or in combination with appropriate additives to make tablets, powders, granules or capsules, for example, with conventional additives, such as lactose, mannitol, corn starch or potato starch; with binders, such as crystalline cellulose, cellulose derivatives, acacia, corn starch or gelatins; with disintegrators, such as corn starch, potato starch or sodium carboxymethylcellulose; with lubricants, such as talc or magnesium stearate; and if desired, with diluents, buffering agents, moistening agents, preservatives and flavoring agents.

[0062] The agents may be formulated into preparations for injection by dissolving, suspending or emulsifying them in an aqueous or nonaqueous solvent, such as vegetable or other similar oils, synthetic aliphatic acid glycerides, esters of higher aliphatic acids or propylene glycol; and if desired, with conventional additives such as solubilizers, isotonic agents, suspending agents, emulsifying agents, stabilizers and preservatives.

[0063] The agents may be utilized in aerosol formulation to be administered via inhalation. The compounds of the present invention may be formulated into pressurized acceptable propellants such as dichlorodifluoromethane, propane, nitrogen and the like.

[0064] Furthermore, the agents may be made into suppositories by mixing with a variety of bases such as emulsifying bases or water-soluble bases. The compounds of the present invention may be administered rectally via a suppository. The suppository may include vehicles such as cocoa butter, carbowaxes and polyethylene glycols, which melt at body temperature, yet are solidified at room temperature.

[0065] Unit dosage forms for oral or rectal administration such as syrups, elixirs, and suspensions may be provided wherein each dosage unit, for example, teaspoonful, tablespoonful, tablet or suppository, contains a predetermined amount of a pharmacological agent. Similarly, unit dosage forms for injection or intravenous

administration may include the pharmacological agent(s) in a composition as a solution in sterile water, normal saline or another pharmaceutically acceptable carrier.

[0066] The term "unit dosage form," as used herein, refers to physically discrete units suitable as unitary dosages for human and animal subjects, each unit containing a predetermined quantity of pharmacological agent(s) of the present invention calculated in an amount sufficient to produce the desired effect in association with a pharmaceutically acceptable diluent, carrier or vehicle. The specifications for the novel unit dosage forms of the present invention depend on the particular pharmacological agent(s) employed and the effect to be achieved, and the pharmacodynamics associated with each pharmacological agent(s) in the subject.

[0067] The pharmaceutically acceptable excipients, such as vehicles, adjuvants, carriers or diluents, are readily available to the public. Moreover, pharmaceutically acceptable auxiliary substances, such as pH adjusting and buffering agents, tonicity adjusting agents, stabilizers, wetting agents and the like, are readily available to the public.

[0068] Those of skill in the art will readily appreciate that dose levels may vary as a function of the specific pharmacological agent(s), the nature of the delivery vehicle, and the like. Dosages for a given pharmacological agent(s) are readily determinable by those of skill in the art by a variety of means.

[0069] Introduction of an effective amount of a pharmacological agent(s) into a subject as described above results in a modulation of the autonomic nervous system, where the modulation may be temporary or permanent.

[0070] A wide variety of different pharmacological agents may be employed in the practice of the subject methods, where the particular pharmacological agent(s) employed to modulate the autonomic nervous system to increase parasympathetic activity relative to sympathetic activity will depend on the subject being treated, the condition being treated, whether it is desired to increase activity in the parasympathetic system and/or decrease activity in the sympathetic system, etc. Representative pharmacological agents include, but are not limited to, magnesium and magnesium variants, e.g., magnesium sulfate; cholinergics, e.g., Bethanechol, Oxotremorine, Methacholine, Cevimeline; Acetylcholinesteriase inhibitors, e.g., Edrophonium, Neostigmine, Donepezil, Tacrine, Echothiophate, Diisopropylfluorophosphate, Demecarium, Pralidoxime, Galanthamine,

Tetraethyl pyrophosphate, Parathoin, Malathion, Isoflurophate, Metrifonate, Physostigmine, Rivastigmine. Abenonium acetylchol, Carbaryl acetylchol, Propoxur acetylchol, Aldicarb acetylchol; catecholamines inhibitors; nicotine and Muscarinics, e.g., Muscarine, Pilocarpine. For example, neurotoxins such as botox and capsaicin may be employed, e.g., delivered locally, to disable sympathetic function such that the parasympathetic to sympathetic ratio is increased. Accordingly, one or more of the above mentioned pharmacological agents may be used in the practice of the subject invention.

Electrostimulatory Devices

[0071] A number of different devices may be employed in accordance with the subject invention to electrically modulate a subject's autonomic nervous system to increase parasympathetic activity relative to sympathetic activity, where such devices are herein referred to as electrostimulatory devices. Such devices may be positioned directly on a targeted area, e.g., positioned below the skin of a subject directly on or adjacent a portion of the autonomic nervous system (e.g., one or more nerve fibers) such as an implantable device, or may be an external device (i.e., some or all of the device may be external to the subject. In accordance with the subject invention, one or more electrodes or electrical contacts may be positioned directly on or adjacent a targeted area of the autonomic nervous system, i.e., directly on or adjacent a portion of the parasympathetic and/or sympathetic system, where the one or more electrodes may be surgically implanted directly on or adjacent a targeted nerve fiber of a subject. In further describing the subject invention, a single electrode is described however it is to be understood that multiple electrodes may be employed and features and characteristics of the single electrode described herein are applicable to any other electrodes that may be employed in the practice of the subject invention.

[0072] An electrostimulatory device typically includes a stimulator such as an electrode, a controller or programmer and one or more connectors for connecting the stimulating device to the controller. In certain embodiments more than one electrode may be employed. In further describing representative electrodes, such are described in the singular, but it will be apparent that more than one electrode may be used, where such may be the same or may be different in one or more aspects. Accordingly, the description

of a representative electrode suitable for use in the subject methods is applicable to other electrodes that may be employed.

[0073] The electrode employed in the subject invention is controllable to provide output signals that may be varied in voltage, frequency, pulse width, current and intensity. The electrode is typically one that provides both positive and negative current flow from the electrode and/or is capable of stopping current flow from the electrode and/or changing the direction of current flow from the electrode. For example, embodiments include an electrode that is controllable in these respects, i.e., controllable in regards to producing positive and negative current flow from the electrode, stop current flow from the electrode, change direction of current flow from the electrode, and the like. In certain embodiments, the electrode has the capacity for variable output, linear output and short pulse width.

[0074] The energy source for the electrical output is provided by a battery or generator such as a pulse generator that is operatively connected to the electrode. The energy source may be positioned in any suitable location such as adjacent to the electrode (e.g., implanted adjacent the electrode), or a remote site in or on the subject's body or away from the subject's body in a remote location and the electrode may then be connected to the remotely positioned energy source using wires, e.g., may be implanted at a site remote from the electrode or positioned outside the subject's body in certain instances. Of interest are implantable generators analogous to a cardiac pacemaker.

[0075] The electrode may be mono-polar, bipolar or multi-polar. In order to minimize the risk of an immune response triggered by the subject against the device and minimize damage such as corrosion and the like to the device from other biological fluids, etc., the electrode and any wires and optional housing materials are made of inert materials such as for example silicon, metal, plastic and the like. For example, a multi-polar electrode having about four exposed contacts (e.g., cylindrical contacts may be employed.

[0076] A variety of methods may be used to endoscopically or surgically implant the electrode on or adjacent at least a portion of the autonomic nervous system such as on or adjacent one or more nerve fibers of the parasympathetic nervous system and/or sympathetic system. Because some nerve fibers may be in very close proximity to one another within a very small area, an analogous technique may generally be employed to

provide operable placement of the electrode on or adjacent to any targeted area of the autonomic nervous system. Accordingly, for purposes of the following discussion, it shall be assumed that the inventive method of surgical implantation is being employed to implant the electrode on or adjacent to the vagus nerve, where such is for exemplary purposes only and is in no way intended to limit the scope of the invention. It should also be understood that, because the region in which the vagus nerve resides is very small, application of electrical impulses to the vagus nerve, even when the electrode is placed directly on the vagus nerve may also affect one or more other nerves.

[0077] A controller or programmer is also typically included in an electrostimulatory device. The programmer is typically one or more microprocessors under the control of a suitable software program. Other components of the programmer will be apparent to those of skill in the art, e.g., analog to digital converter, etc.

[0078] The electrostimulatory device is typically pre-programmed for desired parameters. In many embodiments the parameters are controllable such that the electrode signal may be remotely modulated to desired settings without removal of the electrode from its targeted position. Remote control may be performed, e.g., using conventional telemetry with an implanted electric signal generator and battery, an implanted radiofrequency receiver coupled to an external transmitter, and the like. In certain embodiments, some or all parameters of the electrode may be controllable by the subject, e.g., without supervision by a physician. For example, a magnetic signal may be employed. In such embodiments, one or more magnets may be employed such that upon bringing a magnet in proximity to or away from the power source such as a pulse generator, the magnet may be employed to interfere with the electronic circuitry thus modulating the power – either increasing or decreasing the power supplied depending on whether the magnet is brought in proximity or moved away from the power source.

[0079] FIG. 1 shows an exemplary embodiment of a subject electrostimulatory device 100. Device 100 may be implanted as shown in the abdomen or any other suitable portion of a subject's body 10. One or more leads 23 are shown positioned to electrically stimulate and/or inhibit activity in one or more area of the autonomic nervous system. Device 100 include energy source 14 which may take the form of a modified signal generator Model 7424 manufactured by Medtronic, Inc. under the trademark Intrel II.

Lead 23 may take the form of any suitable lead, such as any of the leads that are sold with the Model 7427 and is coupled to energy source 14 by one or more conventional conductors 16 and 18. Lead 23 may include a paddle lead, a lead having one or more electrodes and/or catheters, or a combination catheter /lead capable of providing electrical impulses and pharmacological delivery. In certain embodiments, a lead may be composed of concentric tubes such as made of platinum or other like material. The tubes may be coated with a polymer except for the distal portions that may serve as the electrodes. Conductive wires carrying energy to the electrodes may be in the interior of the concentric tubes. Optionally, a distal electrode end may include a small recording microelectrode to help assist in the actual placement of the lead.

[0080] As noted above, the present invention may be operated as an open-loop controlled system. In an open-loop system, the physician or patient may at any time manually or by the use of pumps or motorized elements adjust treatment parameters such as pulse amplitude, pulse width, pulse frequency, or duty cycle. Optionally, the present invention may incorporate a closed-loop control system which may automatically adjust the electrical parameters in response to a sensed symptom or an important related symptom indicative of the extent of the condition being treated. Under a closed-loop feedback system to provide automatic adjustment of parameters of the electrodes, a sensor that senses a condition of the body is utilized. More detailed descriptions of sensors that may be employed in the practice of the subject invention, and other examples of sensors and feedback control techniques that may be employed are disclosed in U.S. Pat. No. 5,716,377, which is incorporated herein by reference.

[0081] As shown in FIG. 1, the distal end of lead 23 terminates in one or more therapy delivery elements such as stimulation electrodes which may be implanted on or about a portion of the autonomic nervous system using conventional surgical techniques. The type of treatment that is desired determines the location of the electrodes. Any number of electrodes may be used for various applications. Each of the electrodes is usually individually connected to energy source 14 through lead 23 and conductors 16 and 18. Lead 23 may be surgically implanted either by a laminotomy or by a needle.

[0082] Energy source or signal generator 14 may programmed to provide a predetermined stimulation dosage in terms of pulse amplitude, pulse width, pulse

frequency, or duty cycle. As shown, a programmer 20 may be utilized to provide stimulation parameters to the therapy delivery device via any suitable technology, e.g., using telemetry and the like. For example, in using telemetry, programmer 20 may be coupled to an antenna 24 via conductor 22. In certain embodiments, the programmer may be positioned, e.g., implanted, inside body 10. For example, in certain embodiments the programmer may be integrated with the energy source, electrode, etc., for example as a single unit.

[0083] Device 100 may optionally include one or more sensors to provide closed-loop feedback control of the treatment therapy and/or electrode positioning. One or more sensors (not shown) may be attached to or implanted into a portion of a subject's body suitable for detecting a physical and/or chemical symptom or an important related symptom of the body. For example, sensing feedback may be accomplished, e.g., by a mechanical measure within a lead or an ultrasound or other sensor to provide information about the treatment parameters, lead positioning, autonomic nervous system activity, etc. Suitable sensors that may be employed in the practice of the subject invention are described above.

[0084] Operative placement of a suitable electrostimulatory device may be accomplished using any suitable technique. In further describing exemplary techniques, the vagus nerve is used as an exemplary nerve and is in no way intended to limit the scope of the invention. In general, such placement includes localization of an area of the autonomic nervous system, e.g., the vagus nerve, positioning the electrode on or adjacent the area, e.g., the vagus nerve, and attaching the electrode to a power source. However, with regard to attaching the electrode to a power source, it should be understood that electrodes may be employed which make the implantation and/or attachment of a separate power source unnecessary. For example, an electrode may be employed which includes its own power source, e.g., which is capable of obtaining sufficient power for operation from surrounding tissues in the patient's body or which may be powered by bringing a power source external to the patient's body into contact with the patient's skin, or may include an integral power source, and the like. In such instances, the surgical procedure may be completed upon implantation of the electrode on or adjacent to the vagus nerve.

[0085] An electrode introducer needle may be employed to implant the electrode on or proximate to the area of interest, e.g., the vagus nerve. The size of the introducer needle may vary depending on the diameter of the electrode, etc., where in certain embodiments the electrode introducer needle may be a 12-gauge, 14-gauge, 16-gauge, 18-gauge, 20-gauge needle or 22-gauge needle, e.g., an electrode introducer needle available from Radionics in the Sluyter-Mehta kit as SMK 100 mm 2 mm active tip cannula. However, it should be understood that other electrode introducer needles may be used as appropriate to the needs and skill level of the practitioner performing the surgical procedure.

[0086] At least one imaging apparatus such as a CT scan, MRI apparatus, ultrasound apparatus, fluoroscope, or the like, may be employed to monitor the surgical procedure during the localization of the vagus nerve. For exemplary purposes only, the subject method will be described using a fluoroscope, where such is in no way intended to limit the scope of the invention. The subject is placed in a suitable position for access to the vagus nerve, e.g., supine, on a fluoroscopy table, with the patient's nose pointing vertically. The fluoroscope is then adjusted to a straight lateral position. And the entry point for the insertion of the electrode is determined.

[0087] Once the entry point is determined, the skin overlying the entry point is shaved and prepared with antiseptic solution. A 25-gauge needle may be used to inject a subcutaneous local anesthetic (such as, for example, 2 cc of 2% lidocaine) into the skin and subcutaneous tissues overlying the entry point. In addition to the local anesthetic, the patient may be given intravenous sedation and prophylactic antibiotics prior to commencement of the implantation procedure if desired.

[0088] The electrode introducer needle is inserted at the entry point and advanced. The fluoroscope may be adjusted as the needle is advanced. For example, if it is desired to place the electrode on or adjacent to the vagus nerve, the needle may be directed slightly posteriorly to the opening of the pterygoid or Vidian canal. Although the resolution of the fluoroscopy may be limited, it may be used to verify the positioning of the needle on or proximate to the vagus nerve.

[0089] Once the needle is positioned according to whether implantation is desired on or adjacent the vagus nerve for example, the stylet is withdrawn from the electrode introducer needle. A "test" electrode, if employed, used to test the placement of the

electrode introducer needle may then be positioned within the central channel of the needle. If a "test" electrode is not employed, the electrode that is to be employed to modulate the autonomic nervous system may then be positioned within the central channel of the needle. The electrode may then be advanced to the distal tip of the needle to place the electrode on or proximate to the vagus nerve.

[0090] In certain embodiments, the "test" electrode may be a radiofrequency stimulating electrode suitable to electrically stimulate the tissue at the end of the tip of the electrode and verify its position physiologically within the patient, which may be a different electrode than that ultimately implanted within the patient. A suitable radiofrequency stimulating electrode may be 10 cm with a 2-mm non-insulated active tip. The electrode should fit the full length of the central channel of the needle with its non-insulated active tip protruding through the tip of the needle to expose the electrical contacts. An exemplary electrode that may be employed for this purpose electrode is produced by Radionics as the 100 mm thermocouple electrode in the SMK kit. Once the "test" electrode is inserted through the electrode introducer needle with its electrical contacts exposed, it may then be connected to an electrical stimulus/lesion generator for electrical stimulation.

[0091] The frequency of stimulation may be set at any suitable frequency, e.g., at about 50 Hz, and the voltage may be gradually increased until the subject reports tingling commensurate with stimulation of or about the area of interest of the autonomic nervous system, e.g., the vagus nerve. For example, in those embodiments targeting the vagus nerve, the vagus nerve is located in the posterior aspects of the sphenopalatine fossa and as such the electrode introducer needle may be placed in the sphenopalatine fossa as posteriorly as possible so that it may be positioned adjacent to the vagus nerve as it emerges from the pterygoid canal. Repositioning of the electrode may be performed as necessary.

[0092] If a "test" electrode is employed to test the placement of the electrode introducer needle and as such is different from the electrode to be employed to modulate the autonomic nervous system (i.e., the electrode to be implanted if it is desired to implant the electrode that will be employed to modulate the autonomic nervous system), the "test" electrode may then be removed from the electrode introducer needle while the

needle is held firmly in place to prevent displacement. The electrode to be implanted may then be inserted through the central channel of the needle while the needle is held in place at the hub. Once the electrode to be implanted is in position, fluoroscopic imaging and electrical stimulation may be employed to verify the correct positioning of the needle and the electrode. Alternatively, if the electrode used to test the placement of the electrode introducer needle is the electrode to be implanted, the electrode should be left in the final test position.

[0093] Once the implanted electrode is in place, the end of the electrode that is outside the skin is carefully held in place against the skin. The electrode introducer needle may then be slowly removed, leaving the implanted electrode in place. At this point, if desired, a few small subcutaneous sutures may be placed around the electrode to hold it in the desired position.

[0094] Once the needle has been completely removed and the implanted electrode is in the final position, then the proximal part of the electrode that is coming out of the skin may be secured to the skin of the subject, e.g., by adhesive tape. Additionally, a small incision may be made on the skin at the area the electrode exits the face. Then several subcutaneous sutures may be placed around the electrode to hold it in place. The distal end of the electrode may then be connected to an extension wire or catheter, which is tunneled to the subclavicular area, or another region which will house the device used as an energy source for the implanted electrode. The device or devices used to control or stimulate the electrode may be surgically implanted in the desired region by procedures known in the art, such as have been applied in surgical neuromodulation therapies used to treat Parkinson's disease.

[0095] In certain embodiments of the subject invention, an electrode may be utilized which, instead of or in addition to delivering electric impulses to at least a portion of the autonomic nervous system, delivers a pharmacological agent to at least a portion of the autonomic nervous system. For example, an electrode may be used that has a small port at its tip which is connected to a reservoir or pump containing a pharmacological agent. The pharmacological agent delivery electrode may be implanted using an analogous procedure as that described above for the autonomic system modulating-electrode. In certain embodiments the reservoir or pump may also be implanted in the subject's body,

analogous to that described above for the electrical impulse generator. The pharmacological agent delivery electrode may be controllable such that the amount of pharmacological agent delivered, the rate at which the pharmacological agent may be delivered, and the time period over which the pharmacological agent is delivered may be adjusted.

[0096] The above-described methods find use in a variety of different applications, representative types of which are described in greater detail below.

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[0097] The subject methods find use in a variety of applications in which it is desired to treat a subject for a condition caused by an abnormality in the subject's autonomic nervous system. In such methods, at least a portion of a subject's autonomic nervous system is electrically modulated to increase the parasympathetic activity/sympathetic activity ratio. As indicated above, in many embodiments of this type of application, the subject methods are employed to treat a condition in the subject in order to achieve a desired therapeutic outcome.

[0098] The subject methods find use in the treatment of a variety of different conditions in which an abnormality in a subject's autonomic nervous system exists. By treatment is meant that at least an amelioration of the symptoms associated with the condition afflicting the subject is achieved, where amelioration is used in a broad sense to refer to at least a reduction in the magnitude of a parameter, e.g. symptom, associated with the condition being treated. As such, treatment also includes situations where the condition, or at least symptoms associated therewith, are completely inhibited, e.g. prevented from happening, or stopped, e.g. terminated, such that the subject no longer suffers from the condition, or at least the symptoms that characterize the condition. In certain embodiments, the condition being treated is a disease condition.

[0099] A variety of subjects are treatable according to the subject methods. In many embodiments the subjects are "mammals" or "mammalian," where these terms are used broadly to describe organisms which are within the class mammalia, including the orders carnivore (e.g., dogs and cats), rodentia (e.g., mice, guinea pigs, and rats), and primates

(e.g., humans, chimpanzees, and monkeys). In many embodiments, the subjects are humans.

[00100] As noted above, abnormalities in a subject's autonomic nervous system include those characterized by an abnormally high parasympathetic activity or abnormally low parasympathetic activity and/or an abnormally high sympathetic activity or abnormally low sympathetic activity. There are numerous conditions that the inventors of the subject invention have, unexpectedly, discovered are at least partially manifested by abnormal balance of the sympathetic and parasympathetic functions of the autonomic nervous system, particularly those that manifest higher than normal (as defined by those seen in healthy individuals between the ages of about 20 to about 25 years old) ratio of sympathetic function to parasympathetic function, which may be treated in accordance with the subject invention. Examples of conditions that may be treated with the methods of the subject invention include, but are not limited to, cardiovascular diseases, e.g., atherosclerosis, coronary artery disease, hypertension, hyperlipidemia, cardiomyopathy, volume retention; neurodegenerative diseases, e.g., Alzheimer's disease, Pick's disease, dementia, delirium, Parkinson's disease, amyotrophic lateral sclerosis; neuroinflammatory diseases, e.g., viral meningitis, viral encephalitis, fungal meningitis, fungal encephalitis, multiple sclerosis, charcot joint; myasthenia gravis; orthopedic diseases, e.g., osteoarthritis, inflammatory arthritis, reflex sympathetic dystrophy, Paget's disease, osteoporosis; lymphoproliferative diseases, e.g., lymphoma, lymphoproliferative disease, Hodgkin's disease; autoimmune diseases, e.g., Graves disease, hashimoto's, takayasu's disease, kawasaki's diseases, arthritis, scleroderma, CREST syndrome, allergies, dermatitis, Henoch-schlonlein purpura, goodpasture syndrome, autoimmune thyroiditis, myasthenia gravis, Reiter's disease, lupus, rheumatoid arthritis; inflammatory and infectious diseases, e.g., sepsis, viral and fungal infections, wound healing, tuberculosis, infection, human immunodeficiency virus; pulmonary diseases, e.g., tachypnea, fibrotic diseases such as cystic fibrosis, interstitial lung disease, desquamative interstitial pneumonitis, non-specific interstitial pneumonitis, lymphocytic interstitial pneumonitis, usual interstitial pneumonitis, idiopathic pulmonary fibrosis; transplant-related side effects such as rejection, transplant-related tachycardia, renal failure, typhlitis; transplant related bowel dysmotility, transplant-related hyperreninemia; sleep

disorders, e.g., insomnia, obstructive sleep apnea, central sleep apnea; gastrointestinal disorders, e.g., hepatitis, xerostomia, bowel dysmotility, peptic ulcer disease, constipation, post-operative bowel dysmotility; inflammatory bowel disease; endocrine disorders, e.g., hypothyroidism, hyperglycemia, diabetes, obesity, syndrome X; cardiac rhythm disorders, e.g., sick sinus syndrome, bradycardia, tachycardia, QT interval prolongation arrhythmias, atrial arrhythmias, ventricular arrhythmias; genitourinary disorders, e.g., bladder dysfunction, renal failure, hyperreninemia, hepatorenal syndrome, renal tubular acidosis, erectile dysfunction; cancer; fibrosis; skin disorders, e.g., wrinkles, cutaneous vasculitis, psoriasis; aging associated diseases and conditions, e.g., shy dragers, multi-system atrophy, osteoporosis, age related inflammation conditions, degenerative disorders; autonomic dysregulation diseases; e.g., headaches, concussions, post-concussive syndrome, coronary syndromes, coronary vasospasm; neurocardiogenic syncope; neurologic diseases such as epilepsy, seizures, stress, bipolar disorder, migraines and chronic headaches; conditions related to pregnancy such as amniotic fluid embolism, pregnancy-related arrhythmias, fetal stress, fetal hypoxia, eclampsia, preeclampsia; conditions that cause hypoxia, hypercarbia, hypercapnia, acidosis, acidemia, such as chronic obstructive lung disease, emphysema, cardiogenic pulmonary edema, non-cardiogenic pulmonary edema, neurogenic edema, pleural effusion, adult respiratory distress syndrome, pulmonary-renal syndromes, interstitial lung diseases, pulmonary fibrosis, and any other chronic lung disease; sudden death syndromes, e.g., sudden infant death syndrome, sudden adult death syndrome; vascular disorders, e.g., acute pulmonary embolism, chronic pulmonary embolism, deep venous thrombosis, venous thrombosis, arterial thrombosis, coagulopathy, aortic dissection, aortic aneurysm, arterial aneurysm, myocardial infarction, coronary vasospasm, cerebral vasospasm, mesenteric ischemia, arterial vasospasm, malignant hypertension; primary and secondary pulmonary hypertension, reperfusion syndrome, ischemia, cerebral vascular accident, cerebral vascular accident and transient ischemic attacks; pediatric diseases such as respiratory distress syndrome; bronchopulmonary dysplasia; Hirschprung disease; congenital megacolon, aganglionosis; ocular diseases such as glaucoma; and the like.

[00101] For example, conditions that promote maladaptive sympathetic bias may be treated with the subject invention. The inventors of the subject invention have realized

that, unexpectedly, maladaptive sympathetic bias is a distinct syndrome that may be implicated in a number of fatal or potentially fatal conditions. Normally, the sympathetic drive is an adaptive response to dynamic physiological demands of the body. Under certain conditions, the response may become maladaptive. The inventors of the subject invention have realized that dramatic impacts on the health and well-being of an individual, in certain instances, may be related to acute sympathetic challenge in the context of background chronic sympathetic bias.

[00102] Chronic sympathetic bias may occur in various situations. For example, it may occur when the normal sympathetic bias fails to correct a precipitating respiratory or metabolic abnormality. The inventors of the subject invention have realized that conditions such as sudden infant death syndrome ("SIDS"), sudden adult death syndrome ("SADS") including sudden death among pregnant women, obstructive sleep apnea ("OSA") and congestive heart failure ("CHF") may fall in this category and thus are conditions that may be treated, or rather prevented, by the subject invention. Furthermore, sustained sympathetic bias is also noted during pregnancy, presumably as an adaptive response. Some diseases, such as pheochromocytoma, are intrinsically adrenergic. Sympathetic bias may also be a maladaptive component of the aging process attributable to an inexorable functional decline in autonomic regulatory systems. In the context of sympathetic bias, the inventors have realized that an acute sympathetic episode, as a centrally or peripherally mediated response to acute behavioral, metabolic, or physiologic stressors such as fear, injury, hypoxia, hypercarpnia, acidosis, sleep arousal, and physical activity, may increase the likelihood of fatal arrhythmias, QT-related and otherwise.

[00103] For example, conditions related to chronic or acute hypoxia, hypercarpnia and acidosis, including obstructive sleep apnea ("OSA") and other chronic conditions that disturb pO2, pCO2 and pH such as chronic obstructive pulmonary disease ("COPD"), primary pulmonary hypertension ("PPHTN"), secondary pulmonary hypertension ("SPHTN") and the like, may be treated in accordance with the subject invention. Specifically, the inventors of the subject invention have discovered that excess sympathetic activity relative to parasympathetic activity elicited through, or rather a centrally or peripherally mediated response to, various changes in pO2, pH and pCO2, accounts for many of the physiological consequences of OSA and other chronic

conditions that disturb pO2, pCO2 and pH. For example, the inventors have realized that excess sympathetic activity both directly and indirectly (through stimulating inflammation) accounts for the systemic hypertensive disease observed in individual's suffering from OSA. The inventors have realized that many of the inflammatory consequences of OSA, such as hypertension, atherosclerotic disease and insulin resistance are also mediated through excess sympathetic activity relative to parasympathetic activity. Accordingly, the subject methods may be employed to treat OSA and the associated inflammatory conditions, as well as other chronic conditions that disturb pO2, pCO2 and pH levels such as COPD, PPHTN, SPHTN, and the like, by increasing parasympathetic activity relative to sympathetic activity.

[00104] As noted above, the subject methods may be employed to treat or rather prevent sudden infant death syndrome ("SIDS") and sudden adult death syndrome ("SADS"), including sudden death amongst pregnant women. In this regard, the inventors of the subject invention have discovered that in certain instances sympathetic bias may be implicated in SIDS and SADS.

[00105] More specifically, the inventors of the subject invention have unexpectedly realized that a maladaptive shift to sympathetic bias may be a key determinant of SIDS. Heart rate variability (HRV) is often used as a measure of autonomic balance. Decreased HRV, indicating sympathetic bias, has been observed in patients with central hypoventilation and in infants who have later succumbed to SIDS (see for example Edner A, Katz-Salamon M, Lagercrantz H, Ericson M, Milerad J. Heart rate variability in infants with apparent life-threatening events. Acta Paediatr. 2000 Nov;89(11):1326-9). This finding is consistent with other conditions of hypoxia such as respiratory distress syndrome and prenatal hypoxia which decrease HRV and induce tachycardia (see for example Aarimaa T, Oja R. Transcutaneous PO2, PCO_2 and heart rate patterns during normal postnatal adaptation and respiratory distress. Early Hum Dev. 1988 Jan;16(1):3-11), both indicators of sympathetic bias. Infants who experience near-miss SIDS demonstrate tachycardia and decreased HRV (see for example Reid GM. Sudden infant death syndrome: neonatal hypodynamia (reduced exercise level). Med Hypotheses. 2001 Mar;56(3):280-5). Food regurgitation and diaphoresis associated with SIDS may reflect excess sympathetic activity (see for example Kahn A, Groswasser J, Rebuffat E, Sottiaux

M, Blum D, Foerster M, Franco P, Bochner A, Alexander M, Bachy A, Richard P, Verghote M, Le Polain D, Wayenberg L 1992 Sleep and cardiorespiratory characteristics of infants victims of sudden death: a prospective case-control study. Sleep 15: 287–292; Guntheroth WG, Spiers PS. Thermal stress in sudden infant death: Is there an ambiguity with the rebreathing hypothesis? Pediatrics. 2001 Apr;107(4):693-8; Uchino M, Ishii K, Kuwahara M, Ebukuro S, Tsubone H. Role of the autonomic nervous system in emetic and cardiovascular responses in Suncus murinus. Auton Neurosci. 2002 Sep 30;100(1-2):32-40).

[00106] Inciting causes of sympathetic bias may be manifold. Hyperthermia and fever, both of which have known associations with SIDS (see for example Kahn A, Groswasser J, Rebuffat E, Sottiaux M, Blum D, Foerster M, Franco P, Bochner A, Alexander M, Bachy A, Richard P, Verghote M, Le Polain D, Wayenberg L 1992 Sleep and cardiorespiratory characteristics of infants victims of sudden death: a prospective case-control study. Sleep 15: 287–292; Guntheroth WG, Spiers PS. Thermal stress in sudden infant death: Is there an ambiguity with the rebreathing hypothesis? Pediatrics. 2001 Apr;107(4):693-8) are hyperadregnergic states (see for example Rowell LB. Hyperthermia: a hyperadrenergic state. Hypertension. 1990 May;15(5):505-7). Infection and inflammation, which are associated with SIDS (see for example Krous HF, Nadeau JM, Silva PD, Blackbourne BD. A comparison of respiratory symptoms and inflammation in sudden infant death syndrome and in accidental or inflicted infant death. Am J Forensic Med Pathol. 2003 Mar;24(1):1-8.), are also potential causes of sympathetic bias. In certain situations, the adaptive chemoreceptor-mediated sympathetic response of arousal and increased respiration may fail to correct the underlying hypoxia, hypercapnia, and acidosis, leading to a maladaptive sympathetic bias. The association of prone sleeping position, obstructive sleep apnea, and other respiratory conditions with SIDS (see for example Kahn A, Groswasser J, Rebuffat E, Sottiaux M, Blum D, Foerster M, Franco P, Bochner A, Alexander M, Bachy A, Richard P, Verghote M, Le Polain D, Wayenberg L 1992 Sleep and cardiorespiratory characteristics of infants victims of sudden death: a prospective case-control study. Sleep 15: 287–292; American Academy of Pediatrics, Task Force on Infant Sleep Position and Sudden Infant Death Syndrome. Changing concepts of sudden infant death syndrome: implications for infant sleeping

environment and sleep position. Pediatrics.2000; 105 :650 –656; Hoffman HJ, Damus K, Hillman L, Krongrad E. Risk factors for SIDS: results of the National Institute of Child Health and Human Development SIDS Cooperative Epidemiological Study. Ann N Y Acad Sci 1988; 533: 13-30) may exemplify this phenomenon. In infants with OSA, as with their adult counterparts, the sympathetic bias can exacerbate sleep disturbance and can trigger insomnia (see for example Harrison GA. Stress, catecholamines, and sleep. Aviat Space Environ Med 1985; 56:651-653; Montagna P, Gambetti P, Cortelli P, Lugaresi E. Familial and sporadic fatal insomnia. Lancet Neuro 2003 Mar; 2(3):167-176.), leading to a pernicious cycle.

[00107] Sympathetic bias has an association with QT interval prolongation, a risk factor for sudden cardiac death in adults (see for example Esposito K, Marfella R, Gualdiero P, Carusone C, Pontillo A, Giugliano G, Nicoletti G, Giugliano D. Sympathovagal Balance, Nighttime Blood Pressure, and QT Intervals in Normotensive Obese Women. Obes Res. 2003 May;11(5):653-9). Sympathetic bias may predispose infants to similar risks. A significant association between prolonged QT interval and SIDS victims or those who experienced apparent life-threatening event (ALTE) has been noted (see for example Goldhammer EI, Zaid G, Tal V, Jaffe M, Abinader EG. QT dispersion in infants with apparent life-threatening events syndrome. Pediatr Cardiol. 2002 Nov-Dec;23(6):605-7; Schwartz PJ, Stramba-Badiale M, Segantini A, et al. Prolongation of the QT interval and the sudden infant death syndrome. N Engl J Med.1998; 338 :1709 –1714). Various theories for this association have been proposed, including development-related abnormalities in cardiac sympathetic innervation and genetic predisposition (see for example Stramba-Badiale M, Lazzarotti M, Schwartz PJ. Development of cardiac innervation, ventricular fibrillation, and sudden infant death syndrome. Am J Physiol 1992;263:H1514-H1522; Ackerman, M. J., Siu, B. L., Sturner, W. Q., Tester, D. J., Valdivia, C. R., Makielski, J. C., Towbin, J. A. (2001). Postmortem Molecular Analysis of SCN5A Defects in Sudden Infant Death Syndrome. JAMA 286: 2264-2269; Schwartz PJ. Cardiac sympathetic innervation and the sudden infant death syndrome: a possible pathogenetic link. Am J Med 1976;60:167-172). The inventors of the subject methods have realized that maladaptive sympathetic response is the key determinant of SIDS, a broader view than that which had been held prior to the inventor's view.

[00108] The inventors of the subject invention have also realized that, unexpectedly, sudden death precipitated by maladaptive sympathetic bias, similar to those seen in infants, may account for a proportion of SADS cases.

[00109] For example, while obviously multifactorial in mechanism, conditions such as constipation, insomnia, erectile dysfunction, hypertension are endemic among the aged and are consistent with a broad physiologic bias towards sympathetic function. HRV and baroreflex sensitivity decreases with aging (see for example Stratton JR, Levy WC, Caldwell JH, Jacobson A, May J, Matsuoka D, Madden K. Effects of aging on cardiovascular responses to parasympathetic withdrawal. J Am Coll Cardiol. 2003 Jun 4;41(11):2077-83), consistent with a shift to sympathetic bias. The inventors have realized that, as in SIDS, some cases of SADS may reflect maladaptive chemoreceptor response to hypoxia, hypercapnia, and acidosis, all of which are common conditions seen in the elderly due to myriad of diseases. Examples of chronic diseases that exemplify this phenomenon include renal failure, congestive heart failure, chronic obstructive lung disease ("COPD") and chronic pain (see for example Wiggers H, Botker HE, Egeblad H, Christiansen EH, Nielsen TT, Molgaard H. Coronary artery bypass surgery in heart failure patients with chronic reversible and irreversible myocardial dysfunction: effect on heart rate variability. Cardiology. 2002;98(4):181-5). Heightened sympathetic function is seen in many other conditions including pheochromocytoma, autoimmune conditions, and collagen vascular diseases (see for example Lagana B, Gentile R, Vella C, Giovani A, Tubani L, Mastrocola C, Baratta L, Bonomo L. Heart and autonomic nervous system in connective tissue disorders. Recenti Prog Med. 1997 Dec;88(12)579-84; P.K. Stein, P. Nelson, J.N. Rottman et al., Heart rate variability reflects severity of COPD in PiZ alpha-1-antitrypsin deficiency. Chest 113 (1998), pp. 327–333). More broadly, the inventors have realized that attrition of parasympathetic function with aging may be an important but until now, unrecognized, culprit in generalized sympathetic bias of aging. For example, it has been observed that QT interval lengthens with aging and other chronic conditions that promote sympathetic bias such as COPD (see for example Wei, J. Y., Spurgeon, H. A. and Lakatta, E. G. (1984) Excitation-contraction in rat myocardium: alteration with adult aging. Am. J. Physiol. 246, H784–H791; Tukek T, Yildiz P, Atilgan D, Tuzcu V, Eren M, Erk O, Demirel S, Akkaya V, Dilmener M, Korkut F. Effect of

diurnal variability of heart rate on development of arrhythmia in patients with chronic obstructive pulmonary disease. Int J Cardiol. 2003 Apr;88(2-3):199-206), putting the patient at increased risk of fatal arrhythmias.

[00110] Still further, pregnant women may exhibit various signs of sympathetic bias such as hyperemesis, hypertension, and increased cardiac output, and as such may be treated in accordance with the subject invention. More specifically, the inventors of the subject invention have realized that sympathetic bias in pregnant women may be responsible for sudden death in pregnant women. The shift to sympathetic bias may represent adaptations to the physiologic and immunologic demands of gestation (see for example Minagawa M, Narita J, Tada T, Maruyama S, Shimizu T, Bannai M, Oya H, Hatakeyama K, Abo T. Mechanisms underlying immunologic states during pregnancy: possible association of the sympathetic nervous system. Cell Immunol. 1999 Aug 25;196(1):1-13). Pregnancy is associated with QT prolongation, increased plasma catecholamine levels, and decreased HRV, similar to the other augmented sympathetic states that increase risk for sudden death (see for example Gowda RM, Khan IA, Mehta NJ, Vasavada BC, Sacchi TJ.Cardiac arrhythmias in pregnancy: clinical and therapeutic considerations. Int J Cardiol. 2003 Apr;88(2-3):129-33; N. D. Avery1, L. A. Wolfe, C. E. Amara, G.A.L. Davies, and M. J. McGrath. Effects of human pregnancy on cardiac autonomic function above and below the ventilatory threshold J Appl Physiol 90: 321-328, 2001; Vol. 90, Issue 1, 321-328, January 2001). While an increase rate of sudden deaths from arrhythmias has been noted in pregnant women and has been attributed to hormonal influences (see for example Wolbrette D. Treatment of arrhythmias during pregnancy. Curr Womens Health Rep. 2003 Apr;3(2):135-9; Wolbrette D, Naccarelli G, Curtis A, Lehmann M, Kadish A. Gender differences in arrhythmias. Clin Cardiol. 2002 Feb;25(2):49-56), the subject inventors have realized that sympathetic excess of pregnancy may be a potential cause. The most common manifestation of exaggeration of the normal sympathetic shift in pregnant women may be pre-eclampsia, which accounts for 80% of maternal mortality in developing countries (see for example Conz PA, Catalano C. Pathogenesis of pre-eclampsia. G Ital Nefrol. 2003 Jan-Feb;20(1):15-22). Measurement of post-ganglionic action potentials reveal mean sympathetic activity to be three times higher in pre-eclamptic women compared with healthy pregnant women, and

two times higher compared with the hypertensive non-pregnant women (see for example Schobel HP, Fischer T, Heuszer K, Geiger H, Schmieder RE. Preeclampsia - a state of sympathetic overactivity. N Engl J Med 1996; 335:1480-1485). HRV is reduced in pre-eclamptic women (see for example Yang CC, Chao TC, Kuo TB, Yin CS, Chen HI. Preeclamptic pregnancy is associated with increased sympathetic and decreased parasympathetic control of HR. Am J Physiol Heart Circ Physiol. 2000 Apr;278(4):H1269-73). Autonomic imbalance appears to particularly affect the central nervous system. Seizures, a common morbidity of pre-eclampsia, and acute cerebral vasoconstriction, the most common cause of mortality, may both be viewed as acute adrenergic phenomenon (see for example Novak V V, Reeves LA, Novak P, Low AP, Sharbrough WF. Time-frequency mapping of R-R interval during complex partial seizures of temporal lobe origin. J Auton Nerv Syst. 1999 Sep 24;77(2-3):195-202). Seizure is also a common presentation among the aged, with 25% of new cases of epilepsy diagnosed in the elderly (see for example Stephen LJ, Brodie MJ. Epilepsy in elderly people. Lancet. 2000 Apr 22;355(9213):1441-6).

[00111] Furthermore, as noted above, the subject invention may be employed to treat or prevent congestive heart failure ("CHF"), another situation in which chronic sympathetic bias may be implicated as an underlying cause.

[00112] The inventors of the subject invention have also discovered that, unexpectedly, many conditions of aging are manifestations of sympathetic bias that is unmasked by withdrawal of autonomic function, particularly the parasympathetic system. For example, in regards to employing the subject methods in the treatment of aging associated conditions, the inventors of the subject invention have realized that many clinical consequences of aging are pleiotropic manifestations of the loss of parasympathetic function that occurs during post-reproductive senescence. The inventors realized that the loss of parasympathetic function unmasks the baseline sympathetic bias inherent in the end-organs, resulting in the familiar signs of aging including tachycardia, constipation, insomnia, erectile dysfunction, fluid retention, and systemic inflammation. These consequences in turn may contribute to many of the common diseases associated with aging including type-2 diabetes, Alzheimer's, atherosclerosis, and cancer. Maintenance

and restoration of parasympathetic function may enable upstream control over the deleterious aspects of inherent end-organ adrenergic bias.

[00113] More specifically, aging is marked by a compendium of physiologic and biologic dysfunctions. The inventors of the subject invention have realized that many seemingly unrelated consequences of aging are, at least in part, manifestations of a single upstream phenomenon: an emergent sympathetic bias that is unmasked by loss of parasympathetic function during post-reproductive senescence and may be treated using the subject methods. Common symptomatic presentations among the elderly include dysphagia, constipation, insomnia, anorexia, bladder dysfunction, hypertension, erectile dysfunction, and heart arrhythmias. These symptoms are the final common pathways of many different complex physiologic disturbances and iatrogenic circumstances. These symptoms also represent the classic organ-specific manifestations of excess adrenergic tone.

[00114] The inventors of the subject invention realized that if sympathetic excess is the dominant biologic theme during senescence, the mechanisms may be a loss of parasympathetic function. It is known that the vagus nerve shows decreased activity with age (see for example Tulppo M.P., Makikallio T.H., Seppanen T., et al. Vagal modulation of heart rate during exercise: effects of age and physical fitness. Am J Physiol 1998 Feb; 274(2 Pt 2): H424-9). In the gastrointestinal system, the attrition of vagal and myenteric innervation has been noted with advancing age (see for example Phillips R.J., Powley T.L. As the gut ages: timetables for aging of innervation vary by organ in the Fischer 344 rat. J Comp Neurol 2001 Jun 4; 434(3):358-77). In the bladder, waning parasympathetic function has been noted and is one of the targets for treating dysfunctional bladder (see for example Anderson K.E., Hedlund P. Pharmacologic perspective on the physiology of the lower urinary tract. Urology 2002 Nov; 60(5 Suppl 1):13-20).

[00115] The inventors of the present invention have also realized that loss of parasympathetic tone may also explain the somewhat paradoxical emergence of bradycardia during aging. The cardiac conduction system displays decreased intrinsic function with age, often termed the "sick sinus syndrome". As aging and senescence occurs, the heart loses parasympathetic innervation without concomitant decrease in

sympathetic function (see for example Brodde O.E., Konschak U., Becker K. et al. Cardiac muscarinic receptors decrease with age. In vitro and in vivo studies. J Clin Invest 1998 Jan 15; 101(2):471-8; Ebert T.J., Morgan B.J., Barney J.A., et al. Effects of aging on baroreflex regulation of sympathetic activity in humans. Am J Physiol 1992 Sep; 263(3 Pt 2):H798-803). The adrenergic excess eventually induces focal inflammation and fibrosis of the conduction system irrespective of ischemic changes (see for example Fujino M., Okada R., Arakwa K. The relationship of aging to histological changes in the conduction system of the normal human heart. Jpn Heart J 1983 Jan; 24(1):13-20). Thus, despite the local sympathetic bias, bradycardia ensues.

[00116] Accordingly, the inventors of the subject invention realized that the end-organs of autonomic innervation are intrinsically sympathetic, thus resulting in the failure of the autonomic system to rebalance through the reduction of sympathetic tone-thereby offsetting the lost parasympathetic function-as vagal innervation generally wanes with aging. Accordingly, the inventors of the subject invention have realized that the end-organs of autonomic innervation are instrinsically sympathetic, and in the absence of regulation, they exhibit tonically adrenergic activity that cannot be mitigated by a decrease in extrinsic sympathetic signal. As such, the inventors of the subject invention realized that the excess sympathetic tone is not likely to be attributable to generalized elevation in circulating catecholamines. Thus, the loss of parasympathetic function with aging may be viewed as the unmasking the intrinsic sympathetic activity of end-organs, yielding clinical consequences similar to those associated with aging.

[00117] One of the most profound iterations of this theme may be the link between the autonomic and immune systems, in particularly the link between autonomic balance and Th-1/Th-2 balance. The superimposition of lifespan data on autonomic balance and Th-1/Th-2 balance (graph 1) demonstrates simultaneous peaking of relative parasympathetic and Th-1 functions during reproductive adulthood, followed by a gradual loss of these functions during the ensuing senescence. Co-migration of these functions over the lifespan suggests some link between the two functions and the autonomic system may in part be responsible for governing Th-1/Th-2 balance both regionally and systemically through innervations of various targets including the adrenal glands and lymphoid tissues.

[00118] The inventors of the subject invention have realized the dysregulation of inflammation resulting from the waning parasympathetic tone may be implicated in the susceptibility of the elderly to many other conditions such as atherosclerotic disease, cancer, osteoporosis, viral infections, allergic conditions, and sepsis. As such, the subject methods may be employed to electrically modulating a subject's autonomic nervous to treat aging-related conditions, including age-related disease conditions.

[00119] Accordingly, as described above, the subject methods may be employed in the treatment of a wide variety of conditions. For example, as noted above cardiovascular conditions, including diseases, such as atherosclerosis, coronary artery disease, hypertension, hyperlipidemia, eclampsia, pre-eclampsia, cardiomyopathy, volume retention, and the like, may be treated in accordance with the subject invention. Accordingly, branches of the autonomic nervous system that may be modulated to provide an increase in parasympathetic bias relative to sympathetic bias include but are not limited to, parasympathetic nerve and ganglia such as one or more of the vagus nerve, cardiac and pulmonary plexuses, celiac plexus, hypogastric plexus and pelvic nerves may be modulate to provide the desired increase in parasympathetic bias relative to sympathetic bias. In addition to or instead of modulating parasympathetic activity, cardiovascular diseases may be treated by modulating branches of the sympathetic nerve and ganglia such as one or more of the cervical sympathetic ganglia, dorsal and ventral rami of spinal nerves, coccygeal ganglia, postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, sympathetic nerves to cardiac and pulmonary plexuses, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, lumber splanchnic nerves, celiac ganglion, superior mesenteric ganglion, lumbar splanchnic nerves, may be modulate to provide the desired increase in parasympathetic bias relative to sympathetic bias.

[00120] As described above, the subject methods may also be employed to treat neurodegenerative conditions, including diseases, such as Alzheimer's disease, Pick's disease, Parkinson's disease, dementia, delerium, amyotrophic lateral sclerosis; neuroinflammatory diseases, e.g., viral meningitis, viral encephalitis, fungal meningitis, fungal encephalitis, multiple sclerosis, charcot joint, and the like. Branches of the

autonomic nervous system that may be modulated in accordance with the subject invention to treat neurodegenerative diseases include parasympathetic nerve and ganglia such as, but not limited to one or more of the vagus nerve, cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion and/or sympathetic nerve and ganglia such as, but not limited to one or more of cervical sympathetic ganglia.

[00121] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat orthopedic inflammatory diseases, e.g., osteoarthritis, reflex sympathetic dystrophy, osteoporosis, regional idiopathic, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the vagus nerve and/or sympathetic nerve and ganglia such, but not limited to one or more of the spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, muscle, adipose tissue) and sympathetic chain ganglia.

[00122] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat inflammatory conditions, including diseases, such as multiple sclerosis and rheumatoid arthritis, migraines and chronic headaches, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus and pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00123] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat lymphoproliferative conditions, including diseases, e.g., lymphoma, lymphoproliferative disease, Hodgkin's disease; autoimmune diseases, e.g., Graves disease, hashimoto's, takayasu's disease, kawasaki's diseases, arteritis, scleroderma, CREST syndrome, allergies, dermatitis, Henoch-schlonlein purpura,

goodpasture syndrome, autoimmune thyroiditis, myasthenia gravis, lupus, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus and pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00124] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat inflammatory conditions, including disease, and infectious diseases, e.g., sepsis, diseases of wound healing, viral and fungal infections, wound healing, tuberculosis, infection, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00125] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat pulmonary conditions, including diseases, e.g., tachypnea, fibrotic diseases such as cystic fibrosis, interstitial lung disease, desquamative interstitial pneumonitis, non-specific interstitial pneumonitis, lymphocytic interstitial pneumonitis, usual interstitial pneumonitis, idiopathic pulmonary fibrosis; transplant-related side effects, and the like, include parasympathetic nerve and ganglia such as, but

not limited to one or more of the vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00126] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat gastrointestinal disorders, including diseases, e.g., hepatitis, xerostomia, bowel mobility, peptic ulcer disease, constipation, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the vagus nerve, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00127] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat endocrine disorders, including diseases, e.g., hypothyroidism, diabetes, obesity, syndrome X, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00128] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat cardiac rhythm disorders, e.g., sick sinus syndrome, bradycardia, tachycardia, arrhythmias, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the vagus nerve, cardiac and pulmonary plexus and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), cardiac and pulmonary plexus.

[00129] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat genitourinary conditions, including diseases, e.g., bladder dysfunction, renal failure, erectile dysfunction; cancer, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00130] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat skin conditions, including diseases, e.g., wrinkles, cutaneous vasculitis, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the vagus nerve and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia such as, but not limited to one or more of the spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia and coccygeal ganglia.

[00131] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat aging associated conditions, including diseases, e.g., shy dragers, multi-symptom atrophy, age related inflammation conditions, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary

ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00132] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat Th-2 dominant conditions, including diseases, e.g., typhlitis, osteoporosis, lymphoma, myasthenia gravis, lupus, and the like, include parasympathetic nerve and ganglia such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00133] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat autonomic dysregulation conditions, including diseases; e.g., headaches, concussions, post-concussive syndrome, coronary syndromes, coronary vasospasm; chronic pain and congestive heart failure, and the like, including parasympathetic nerve and ganglia such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood

vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00134] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat conditions, including diseases, that cause hypoxia, hypercarbia, and/or acidosis, such as chronic obstructive pulmonary disease ("COPD"), emphysema, any chronic lung disease that causes acidosis; sudden death syndromes, e.g., sudden infant death syndrome, sudden adult death syndrome, and the like, including parasympathetic nerve and ganglia such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00135] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat conditions, including diseases, such as QT interval prolongation, acute pulmonary embolism, chronic pulmonary embolism, deep venous thrombosis, venous thrombosis, arterial thrombosis, coagulopathy, amniotic fluid embolism, pregnancy-related arrhythmias, fetal stress, fetal hypoxia, respiratory distress syndrome, amniotic fluid embolism, myocardial infarction, reperfusion syndrome, ischemia, epilepsy, seizures, stroke, pleural effusion, cardiogenic pulmonary edema, non-cardiogenic pulmonary edema, acute respiratory distress syndrome ("ARDS"), neurogenic edema, hyperreninemia, hepatorenal syndrome, pulmonary renal syndrome, aging, constipation, acidosis of any cause, hypercapnia, acidemia, renal tubular acidosis, aortic dissection, aortic aneurysm, insomnia, sleep disorders, cerebral vascular accident and transient ischemic attacks, and the like, include parasympathetic nerve and ganglia

such as, but not limited to one or more of the cranial nerve III, cranial nerve VII, cranial nerve IX, sphenopalatine ganglion, ciliary ganglion, submandibular ganglion, otic ganglion, vagus nerve, cardiac and pulmonary plexus, celiac plexus, hypogastric plexus, pelvic nerves and/or sympathetic nerve and ganglia such as, but not limited to one or more of the cervical sympathetic ganglia, spinal nerves (dorsal and ventral rami), postganglionic fibers to spinal nerves (innervating skin, blood vessels, sweat glands, erector pili muscle, adipose tissue), sympathetic chain ganglia, coccygeal ganglia, cardiac and pulmonary plexus, greater splanchnic nerve, lesser splanchnic nerve, inferior mesenteric ganglion, celiac ganglion, superior mesenteric ganglion and lumber splanchnic nerves.

[00136] Branches of the autonomic nervous system that may be modulated in accordance with the subject invention to treat sleep apnea include cardiac branches of the sympathetic and parasympathetic systems and baroreceptors and chemoreceptors in the carotid arch and aortic bulb.

DEVICES AND SYSTEMS

[00137] The subject invention also includes devices and systems that may be employed in the practice of the subject methods. The subject systems at least include an electrostimulatory device such that they include at least include one electrode for electrically modifying at least a portion of a subject's autonomic nervous system in accordance with the subject invention, as described above. In many embodiments, the electrostimulatory device is an implantable device, or at least certain components such as one or more electrodes, are implantable. Certain embodiments may include a plurality of electrodes, where some or all may be the same or some or all may be different. For example, at least a first electrode may be provide for electrically stimulating at least a portion of the parasympathetic system and at least a second electrode may be provided for inhibiting activity in at least a portion of the sympathetic system. In certain embodiments, a "test" electrode, as described above, may be included in a system. As noted above, such "test" electrodes may be a radiofrequency stimulating electrode. Still further, one or more electrodes may be included in a system which, instead of or in addition to delivering electric impulses to at least a portion of the autonomic nervous

system, delivers an autonomic nervous system pharmacological agent to at least a portion of the autonomic nervous system. A system according to the subject invention typically also includes an energy source such as a battery or generator, where in certain embodiments the energy source may be implantable, and may also include one or more leads or wires for coupling the one or more electrodes to an energy source. In certain embodiments, the subject systems may include one or more autonomic nervous system pharmacological agents. In such embodiments, suitable delivery means may be included in the subject systems, dictated by the particular pharmacological agent as describe above, e.g., the particular form of the agent such as whether the pharmacological agent is formulated into preparations in solid, semi-solid, liquid or gaseous forms, such as tablets, capsules, powders, granules, ointments, solutions, suppositories, injections, inhalants and aerosols, and the like, and the particular mode of administration of the agent, e.g., whether oral, buccal, rectal, parenteral, intraperiactivityal, intradermal, transdermal, intracheal, etc. Accordingly, certain systems may include a suppository applicator, syringe, I.V. bag and tubing, electrode, etc. Systems may also include one or more devices for delivering, e.g., implanting, an electrosurgical device to a target site of a subject such as into the body cavity of a subject. For example, an endoscope, introducer needle, and the like, may be provided. Systems may also include one or more imaging or scanning apparatuses such as a fluoroscope, CT scan, and the like.

[00138] As described above, a system for use in practicing the subject methods may also include a suitable detector (not shown) for detecting one or more physical and/or chemical aspects related to the autonomic nervous system. The detector at least includes data gathering means. Also provided may be data analysis means where such may be a separate component from or integral with data gathering means, but in many embodiments is operatively coupled to data gathering means, e.g., integral with. In use, data related to one or more aspects of the autonomic nervous system may be collected by data gathering means and forwarded to data analysis means which executes steps necessary to process and evaluate the collected data and determine whether the autonomic nervous system is in need of electrical modulation. Such evaluation may include comparing data to reference values, etc. When present, a detector (or data evaluation means if separate) may be operatively coupled to one or more other elements

of a given electrostimulatory device such that results of the determinations of autonomic modulation may automatically trigger (or cease) activation of electrical energy to the autonomic nervous system. For example, the detector may detect heart rate variability and determine that activity in the parasympathetic system needs to be increased and/or activity in the sympathetic system needs to be decreased. Accordingly, the electrostimulatory device may then be activated to provide the appropriate electrical energy. Suitable detectors include any detector capable of gathering information about the autonomic nervous system and includes both invasive, minimally invasive and non-invasive detectors where in certain embodiments a detector may be an implantable detector. Suitable detectors include, but are not limited to, those capable of collecting data regarding nerve conduction, circulating catecholamine levels, heart rate variability ("HRV"), post-ganglionic action potentials, QT interval, and the like and include, but are not limited to, MRI apparatuses, CT apparatus, neurography apparatuses, cardiovascular monitors, sensors including electrodes, etc.

COMPUTER READABLE MEDIUMS AND PROGRAMMING STORED THEREON

[00139] Any part of the subject methods, e.g., detection, analysis and activation/termination of electrical energy including selecting suitable electrical parameters, may be performed manually or automatically. For example, the subject invention may include suitable computing means such as suitable hardware/software for performing one or more aspects of the subject methods. For example, one or more aspects of the subject invention may be in the form of computer readable media having programming stored thereon for implementing the subject methods. Accordingly, programming according to the subject invention may be recorded on computer-readable media, e.g., any medium that can be read and accessed directly or indirectly by a computer. Such media include, but are not limited to, computer disk or CD, a floppy disc, a magnetic "hard card", a server, magnetic tape, optical storage such as CD-ROM and DVD, electrical storage media such as RAM and ROM, and the hybrids of these categories such as magnetic/optical storage media. One of skill in the art can readily appreciate how any of the presently known computer readable mediums may be used to provide a manufacture that includes a recording of the present programming/algorithm

for carrying out the above-described methodology. Thus, the computer readable media may be, for example, in the form of any of the above-described media or any other computer readable media capable of containing programming, stored electronically, magnetically, optically or by other means. As such, stored programming embodying steps for carrying-out some or all of the subject methods may be transferred to a computer-operated apparatus such as a personal computer (PC) or the like, by physical transfer of a CD, floppy disk, or like medium, or may be transferred using a computer network, server, or other interface connection, e.g., the Internet.

[00140] For example, the subject invention may include a computer readable medium that includes stored programming embodying an algorithm for carrying out some or all of the subject methods, where such an algorithm is used to direct a processor or series of processors to execute the steps necessary to perform the task(s) required of it and as such in certain embodiments the subject invention includes a computer-based system for carrying-out some or all of the subject methods. For example, such a stored algorithm may be configured to, or otherwise be capable of, directing a microprocessor to receive information directly or indirectly from data gathering means (i.e., information collected by data gathering means about the autonomic nervous system) and process that information to determine the state of the autonomic nervous system, e.g., the activity level of the parasympathetic system and/or the sympathetic system and even whether the autonomic nervous system requires modulation, e.g., if the parasympathetic activity is normal or abnormal and/or if sympathetic activity is normal or abnormal, and, if so, the specifics of the modulation that is required. The result of that processing may be communicated to a user, e.g., via audio and/or visual means, e.g., the algorithm may also include steps or functions for generating a variety of autonomic nervous system profile graphs, plots, etc.

[00141] The algorithm may be configured to, or otherwise be capable of, directing a microprocessor to activate, i.e., turn "on" and "off" an electrostimulatory device for applying energy to at least a part of the autonomic nervous system, e.g., in response to the above-described determination of the state of the autonomic nervous system. For example, if it is determined that parasympathetic activity needs to be increased and/or sympathetic activity needs to be decreased, the processor may direct the

electrostimulatory device to provide the appropriate energy to result in the desired action. Accordingly, a processor may select the appropriate parameters (e.g., frequency, amplitude, etc.) depending on what is required and direct an electrostimulatory device to implement the parameters.

[00142] The subject invention may also include a data set of known or reference information stored on a computer readable medium to which autonomic nervous system data collected may be compared for use in determining the state of the autonomic nervous system. The data may be stored or configured in a variety of arrangements known to those of skill in the art.

KITS

[00143] Also provided are kits for practicing the subject methods. While the subject kits may vary greatly in regards to the components included, typically, the kits at least include an electrostimulatory device, as described above. Accordingly, subject kits typically at least include an electrostimulatory device such that they include at least include one electrode for electrically modifying at least a portion of a subject's autonomic nervous system in accordance with the subject invention, as described above. In many embodiments, the electrostimulatory device provided in a kit is an implantable device, or at least certain components such as one or more electrodes, are implantable. Certain kits may include a plurality of electrodes, where some or all may be the same or some or all may be different. For example, certain kits may include at least a first electrode for electrically stimulating at least apportion of the parasympathetic system and at least a second electrode for inhibiting activity in at least a portion of the sympathetic system. In certain embodiments, a subject kit may include a "test" electrode, as described above such as a radiofrequency stimulating electrode. Still further, one or more electrodes may be included in a kit which, instead of or in addition to delivering electric impulses to at least a portion of the autonomic nervous system, delivers an autonomic nervous system pharmacological agent to at least a portion of the autonomic nervous system. Kits according to the subject invention typically also include an energy source such as a battery or generator, where in certain embodiments the energy source may be

implantable, and may also include one or more leads or wires for coupling the one or more electrodes to an energy source.

[00144] Devices for delivering, e.g., implanting, an electrosurgical device to a target site of a subject such as into the body cavity of a subject may also be included in the subject kits. For example, an endoscope, introducer needle, and the like may be provided.

[00145] The subject kits also generally include instructions for how to practice the subject methods and in particular how to use the electrostimulatory device provided in the kit to treat a subject for a condition caused by an abnormality in the subject's autonomic nervous system by electrically modulating at least a portion of the subject's autonomic nervous system to increase parasympathetic activity relative to sympathetic activity. The instructions are generally recorded on a suitable recording medium or substrate. For example, the instructions may be printed on a substrate, such as paper or plastic, etc. As such, the instructions may be present in the kits as a package insert, in the labeling of the container of the kit or components thereof (i.e., associated with the packaging or sub-packaging) etc. In other embodiments, the instructions are present as an electronic storage data file present on a suitable computer readable storage medium, e.g. CD-ROM, diskette, etc. In yet other embodiments, the actual instructions are not present in the kit, but means for obtaining the instructions from a remote source, e.g. via the internet, are provided. An example of this embodiment is a kit that includes a web address where the instructions can be viewed and/or from which the instructions can be downloaded. As with the instructions, this means for obtaining the instructions is recorded on a suitable substrate.

[00146] The subject kits may also include one or more autonomic nervous system pharmacological agents. The dosage amount of the one or more pharmacological agents provided in a kit may be sufficient for a single application or for multiple applications. Accordingly, in certain embodiments of the subject kits a single dosage amount of a pharmacological agent is present.

[00147] In certain other embodiments, multiple dosage amounts of a pharmacological agent may be present in a kit. In those embodiments having multiple dosage amounts of pharmacological agent, such may be packaged in a single container, e.g., a single tube,

bottle, vial, and the like, or one or more dosage amounts may be individually packaged such that certain kits may have more than one container of a pharmacological agent.

[00148] Suitable means for delivering one or more pharmacological agents to a subject may also be provided in a subject kit. The particular delivery means provided in a kit is dictated by the particular pharmacological agent employed, as describe above, e.g., the particular form of the agent such as whether the pharmacological agent is formulated into preparations in solid, semi-solid, liquid or gaseous forms, such as tablets, capsules, powders, granules, ointments, solutions, suppositories, injections, inhalants and aerosols, and the like, and the particular mode of administration of the agent, e.g., whether oral, buccal, rectal, parenteral, intraperiactivityal, intradermal, transdermal, intracheal, etc. Accordingly, certain systems may include a suppository applicator, syringe, I.V. bag and tubing, electrode, etc.

[00149] Some or all components of the subject kits may be packaged in suitable packaging to maintain sterility. In many embodiments of the subject kits, the components of the kit are packaged in a kit containment element to make a single, easily handled unit, where the kit containment element, e.g., box or analogous structure, may or may not be an airtight container, e.g., to further preserve the sterility of some or all of the components of the kit.

[00150] It is evident from the above discussion that the above described invention provides methods, system and kits for treating a subject for a condition caused by an abnormality in said subject's autonomic nervous system which are simple to use, effective, and can be used to treat variety of different conditions. As such, the subject invention represents a significant contribution to the art.

[00151] All publications and patent applications cited in this specification are herein incorporated by reference as if each individual publication or patent application were specifically and individually indicated to be incorporated by reference. The citation of any publication is for its disclosure prior to the filing date and should not be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention.

[00152] Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it is readily apparent to those of ordinary skill in the art in light of the teachings of this invention that certain changes and modifications may be made thereto without departing from the spirit or scope of the appended claims.